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TREATMENT OF EPILEPSY

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TREATMENT OF EPILEPSY

BY

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PREFACE

During the past few years there has been renewed interest in the problem of recurrent convulsions or seizures of unknown cause and as a result a tremendous amount of serious investigation has been undertaken. The conception of this obscure symptom complex has been modified and entirely new methods of treatment have been instituted. Although much has been learned and the newer treatments have brought a far higher percentage of success than was ever hoped for before, many problems are still unsolved and will remain so until the etiology of the condition is fully understood. That the answer to these questions is being seriously sought is evidenced by the fact that at the Tenth Annual Meeting of the Association for Research in Nervous and Mental Diseases held in New York, December 27, 1929, there were on the program twenty-four papers which discussed the subject more or less directly.

The need for research has been appreciated also by Harvard University, which has appointed an Epilepsy Commission, the purpose of which is to carry out a program of research over a period of years. The work overseen by this Commission is now being carried on in three hospitals by selected investigators and is supported by public funds.

On consulting the literature it is obvious that the present-day conception of epilepsy was not clearly outlined in any one publication until Lennox and Cobb's very excellent volume appeared in *Medicine Monographs,* Vol. XIV, Baltimore, 1928. In it, the voluminous literature has been reviewed and evaluated. Their work should form a part of the library of every one interested in the disease complex. This book on treatment is intended to supplement that of Lennox and Cobb, to present the facts which seem to me to be essential for an understanding of the disease from the point of view of the practitioner, and also to outline the practical methods of treatment. Much emphasis has been laid on the theory and use of the ketogenic diet. This, in my judgment, has been used with success for a sufficiently long period to justify its classification among the important new methods of treatment, especially for children. Less has been said of dehydration because it has not been used therapeutically in enough cases to have been satisfactorily evaluated. The technique of both methods, however, is described in considerable detail.

It is my hope that this book will fill the need of the practitioner and will extend the benefits of treatment to a large proportion of the half million epileptics who are believed to exist in the United States.

I am indebted to many friends, especially Dr. George R. Minot, for encouragement and interest in this work. It has been made possible by the enthusiastic work of the Resident Physicians in my clinic at the Massachusetts General Hospital, Doctors Eli C.

Romberg, Gerald N. Hoeffel, Edward B. Shaw, John P. Parsons, Kenneth M. Metcalf, and Eliot H. Luther, with the aid of Miss Margaret E. Moriarty. I am also indebted to Miss Ebba C. Blomquist for aid in carrying out the diets, to Miss Ruth C. Seeliger for preparing the many drafts through which the manuscript has passed, and to Miss Martha Taylor for editing the text. Much of the work received the helpful coöperation of Dr. Stanley Cobb and Dr. William Lennox.

Fritz Bradley Talbot.

Boston, Mass.

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TREATMENT OF EPILEPSY

CHAPTER I

Introduction

Recurrent fits and attacks of unconsciousness have for many centuries been thought in themselves to constitute a disease—the Sacred Disease or Epilepsy (επιλεχια, a seizure)—but as increasing knowledge has demonstrated that pathological conditions of various types may cause similar manifestations, this conception has changed. Physicians now believe that fits and attacks of unconsciousness are symptoms of some fundamental disorders, and are not, *per se,* a disease entity. In spite of this new conception, the term "epilepsy" is still applied to recurrent fits and periods of unconsciousness, for no other more clearly descriptive word has been found.

Although epilepsy is common in mature individuals, it usually begins before the subject is twenty years old, and the condition is, therefore, more closely related to the disorders of childhood than to those of adult life. On this account and also because prompt correction of the condition before irreparable damage has been done and abnormal habits have been established would eliminate serious adult problems, greater emphasis will be given in the following discussion to the treatment of epilepsy during childhood than to its treatment in later life. All phases will, however, be considered.

History

Descriptions of epilepsy may be found in the earliest historical records of disease, and it is possible that even such ancient writings as those of Hippocrates may be merely repetition of facts which were known to physicians in 3500 B.C. (300). As scientific knowledge has increased, the conception of the cause of epilepsy has undergone marked change. During the early stages of civilization the condition was in some regions attributed to temporary loss of the soul from the body, in other regions to possession of the body by some demon or other malignant spirit, then later to "natural causes" (Hippocrates) (1). In primitive countries such beliefs still exist among the natives, but in civilized regions there have been many attempts to discover the true cause of the disorder. Modern scientific research on this problem began during the nineteenth century.

Belief in the production of disease by loss of the soul or some part of it from the body has existed in Indonesia, Papuo-Melanesia, America, West Africa (246), and China (95) and has left its mark upon the type of treatment employed by the natives. At Amoy in China when some mischievous spirit has produced epilepsy by drawing the soul out of the body, definite means are taken to recover the absent soul. If the patient is a child, the mother rushes to the rooftop and waves about in the air a bamboo pole to which one of the child's garments has been attached. While she is doing this she several times calls the child by name and begs it "To come

back, to return home." Another inmate of the house simultaneously bangs a gong to attract the attention of the lost soul to the familiar garment. After this procedure has been carried out, the garment is placed beside the child so that the soul which is supposed to have slipped into it may return to the body. If the child does not die, the people believe that recovery is sure to follow sooner or later. In parts of India the principle of treatment is the same, but the soul is caught in the boots of the sufferer (95).

Where epilepsy is attributed to demoniacal possession, magic and religious rites are employed to drive out the unwanted spirit. In northern India sound thrashing of the patient with a sacred iron chain is supposed immediately to expel the demon (97), and in Bilaspore "when a man has had an epileptic fit he will wear an iron bracelet to keep away the evil spirit which was supposed to have possessed him." (96). A still more curious method of treatment is that used in the Vosges Mountains. There it is believed that if a man drops to the ground with the falling sickness the only procedure needed to make him get up immediately is to whisper in his right ear "Gaspard fert myrrham, thus Melchior, Balthasar aurum." If the cure is to be complete, three nails, each exactly the length of the patient's little finger, must be knocked into the ground on the very spot of the fall, and as each is driven into place the sufferer's name must be spoken (97). Special powers of averting disease seem to be attributed to the Three Kings, for in Western Bohemia an amulet contain-

ing their pictures and a Latin inscription begging their protection has been considered effective in the avoidance of epilepsy and other maladies (97).

The custom of the little church of St. Tecla in Llandegla, Wales, illustrates another type of cure. The patient first washes his limbs in a sacred well near the church, drops fourpence into it as an offering, walks three times around it, and repeats the Lord's Prayer three times. Then a "fowl, which was a cock or a hen according as the patient was a man or a woman, was put into a basket and carried round first the well and afterwards the church. Next the sufferer entered the church and lay down under the communion table till break of day. After that he offered sixpence and departed, leaving the fowl in the church. If the bird died, the sickness was supposed to have been transferred to it from the man or woman, who was now rid of the disorder." This custom is reported to have persisted into the nineteenth century (97). A similar procedure is used in Melanesia. There by chants and long-continued rites, the spirit responsible for epilepsy is transferred to a tree, and the tree is in turn freed by further magic ceremonies so that its fruit can be used (246).

The conception of epilepsy as a contagious disease, which, according to Garrison (104), was common during the Middle Ages, is thought to have sprung from the ancient Assyro-Babylonian belief that the disorder was due to seizure by demons. Patients were not permitted to sell articles of food and drink, and if allowed within city limits at all were strictly iso-

lated. In some regions, for instance at Rufach in upper Alsace, isolation hospitals were founded for the victims of epilepsy as late as the middle of the fifteenth century.

Among other beliefs regarding the cure or prevention of epilepsy should be mentioned those associated with mistletoe. As this plant "cannot fall to the ground because it is rooted on the branch of a tree high above the earth, it seems to follow as a necessary consequence that an epileptic patient cannot possibly fall down in a fit so long as he carries a piece of mistletoe in his pocket or a decoction of mistletoe in his stomach. Such a train of reasoning would probably be regarded even now as cogent by a large portion of the human species" (97a).

From time to time it has been suggested that epilepsy may be in some way associated with such meteorological factors as different phases of the moon or electrical variations of the atmosphere. Special potency has frequently been attributed to mistletoe which was gathered during certain phases of the moon, and even some of the ancient physicians who had begun to make very keen observation of symptoms believed that the moon governs epileptic attacks. This idea is known to have persisted into the nineteenth century, and even now the desire to explain epilepsy by variations in the atmosphere has not been lost. Dannhauser in 1925 (70) published the results of a comparison of the daily incidence of epileptic attacks in 169 male patients with the records of a meteorological station. He could, how-

ever, find no relationship between the incidence of attacks and the pressure, humidity, temperature, and electrical content of the air.

Among the Russian peasants of to-day the subject of an epileptic attack is supposed to be particularly susceptible to outside influences of all sorts. He must not be restrained in any way except to prevent serious physical injury, because every muscle is thought to be so sensitive that the slightest touch may cause excruciating agony. Since the soul is even more sensitive than the body at such times the face must always be covered with a handkerchief or other bit of light cloth lest some onlooker cast an evil influence on the sufferer while he is helpless to resist. Such beliefs as these may probably be traced back to the even more primitive conceptions of loss of the soul, or possession of the body by some unwanted spirit.

In spite of the prevalence and persistence of superstitions about epilepsy, many accurate accounts of the disease appeared in very early literature. The first statement that epilepsy is not a "sacred disease," but rather a disorder which is due to natural causes, was made by Hippocrates (1). He felt that the only reason for ascribing the condition to the gods was the fact that the nature of the disease was incomprehensible. Although this author was unacquainted with experimental methods, he was able to make such accurate observations that his descriptions of epilepsy and other diseases might, according to Garrison, "with a few changes and additions take their place in any modern textbook." He

noticed that epilepsy is not apt to develop after the twentieth year of life, and he believed that seizures were connected with humidity of the brain,—a theory which he supported by data obtained from the dissection of goats. The classical description of the aura of epilepsy was made by Aretæus of Cappadocea in the second or third century, but the writings of Ætius of Byzantium, the physician of Justinian I, which appeared during the sixth century are far more accurate (104). In the centuries which immediately followed, various descriptions of epilepsy were added to the records, but there was little advance in the understanding of the disease until the advent of modern scientific methods of study.

Experimentation comparable to that of to-day was applied to the problem of epilepsy by Brown-Séquard, who published a report on the experimental production of this disorder in 1869 and 1870. At about the same time Hughlings Jackson, a young physician in London, was making important clinical observations. These finally led to the recognition of a special type of epilepsy which has come to be known as Jacksonian. There is no single complete and satisfactory description of this by Hughlings Jackson himself, but his various clinical reports and discussions contain all the data necessary for a full description of the disorder. With the advance of science since the time of these two investigators have come many suggestions about the etiology and treatment of epilepsy, but none has demonstrated the exact nature of the disorder. Heredity, alcoholism,

infection, lesions in the central nervous system, dysfunction of the endocrine glands, digestive disorders, and many other factors have been held responsible for epileptic attacks, although no adequate indication of their fundamental etiological rôle had been found. Within the last decade, investigations have demonstrated that there is almost undoubtedly some intimate relation between the metabolic processes of the body and the symptoms known as epilepsy. Precisely what the relationship is has not yet been discovered, but ample evidence of its existence is to be found in the response of epileptic patients to forms of therapy which are designed to alter the metabolic processes within the body. Thus although a full explanation of the disorder has not yet been found, enough information has been obtained to show that observers are at last on the right track.

That epilepsy is not always an unsurmountable handicap to its victim, even without effective treatment, is amply demonstrated in historical records. The disorder seems to be characteristically associated with marked egocentricity and independence of thought and action—traits which can be of great value when properly used. Just how far these traits are an expression of the epileptic disorder and just how far they can be considered essential parts of the character of an individual is not known. Their appearance in certain of the great figures of history is, however, very striking. Julius Cæsar, Caligula, Germanicus Britannicus, Marlborough, Napoleon, and the Duke of Wellington, who are noted for obstinate

self-sufficiency in military and political affairs, are all said to have been epileptic. Peter the Great and Charles V are supposed to have suffered from the disorder during childhood (266). In religion and art great ability has also been associated with these and other manifestations of epilepsy. There seems to be general agreement that Mohammet was subject to epileptic attacks, and some writers believe that St. Paul's "thorn in the flesh" was this disorder; others, however, cannot find in the facts at hand evidence to justify them in calling his affliction epilepsy (302). Anne Lee, the founder of the Shakers, may have been epileptic. In most instances definite proof of the occurrence of epilepsy in historical figures is difficult to find, for the seizures have been considered a disgrace and every possible effort has been made to hide their occurrence. The report seems to be fairly widespread, however, that Balzac had an attack of epilepsy during childhood, that Dumas had epileptic ancestors, and that Lord Byron was subject to seizures toward the end of his life. Some writers attribute the source of certain incidents in the "Divina Commedia" to the author's epileptic attacks, but without actual proof that Dante suffered from epilepsy. Dostoyeffsky, however, almost certainly derived the material for the description of his epileptic characters from first hand knowledge. Other famous names associated with the disorder are those of Gustav Flaubert, Rachael the great tragic actress, Schiller, H. K. White, Pascal, Handel, Mendelssohn, Mozart, and Paganini (266). From this brief review it can be seen that epilepsy, or a condition closely re-

sembling it, need not prevent great accomplishment. So many people of fame appear to have suffered from the seizures in one form or another, that Lombroso has stated that genius is epileptoid in origin (266). Such a statement is, of course, too sweeping, for genius does not confine itself to the victims of epilepsy. The number of inspired individuals who have been entirely free from the disorder is far larger than the number of those whose genius has carried them to great heights in spite of the handicap. Something far more fundamental than a mere abnormality is needed for great accomplishment. The large percentage of epileptic individuals whose attainments are far below the normal average is proof of this. Only when in a strong personality disease accentuates certain desirable characteristics can it possibly be considered advantageous.

Incidence

Because epilepsy has for centuries been considered a disgrace, and because it is frequently difficult for the uninitiated to recognize its mild or unusual forms, there are no really satisfactory incidence figures. The available statistics show, however, that the disorder occurs in most parts of the world and affects most races. There are a very few regions where it is thought to be non-existent. Thomson (286) is quoted as saying: "As I could never meet with a medical man, nor an European who had seen a native with epilepsy, nor a native who could describe the disease, I am inclined to think it does not exist among (the Maoris) or if it does it must be

very rare." The reported apparent incidence is particularly low among the American Indians of the Pima tribe (127), the natives of Hawaii and the Philippine Islands, the native troops of India, and in the Japanese Navy (73).

TABLE I

THE INCIDENCE RATE OF EPILEPSY IN VARIOUS COMMUNITIES AND COUNTRIES

Figures taken from Davenport (73)

Class, Nationality, or Race	Rate per 1,000
United States	
2,500,000 drafted men	5.15
Scotland Army recruits, 1917 to 1919	6.40
Great Britain	0.3 to 37.0
Denmark, various estimates	1.2 to 4.0
France, recruit statistics	1.6
Germany	
School children of Mecklenburg	1.15
Other areas	2.0
Italy	
Morselli's count of 5,000 Italians	1.2
10,000 military recruits, rejections for epilepsy	11.53
Switzerland	
Amman's estimate for whole country	5.0
Negroes	
United States Draft, Negro Sections, defect found	5.13
Maoris of New Zealand	0.0

In all countries where reasonably significant statistics are available the percentage incidence of epilepsy seems to vary within fairly narrow limits. If the incidence among drafted men in the United States be accepted as applicable to the entire population, calculation will show that about 500,000 individuals in this country are subject to epilepsy (73). Table I, which is an excerpt from Davenport's

(73) larger table, shows the rates of incidence in various communities and countries, and illustrates the lack of really comparable figures. There seems to have been no uniformity in the methods used to collect data. The very high apparent incidence in certain small communities is probably due to improper interpretation of statistics or to special conditions, and cannot be considered of general significance.

Age Incidence.—Although by far the majority of subjects are adults, epilepsy should be considered a disorder of childhood and youth because it most often begins during the early years of life. According to Webber the incidence is highest in the second decade of life, and very low after the twentieth

TABLE II

AGE OF ONSET OF EPILEPSY IN ALL PATIENTS ADMITTED TO CRAIG COLONY UP TO JANUARY 1, 1926 *

Age at Onset	Number of Cases	Percentage of Total
Birth to 5 years	1,830	27.7
5 to 10 "	1,107	16.7
10 to 15 "	1,190	18.0
15 to 20 "	892	12.0
20 to 25 "	389	5.8
25 to 30 "	220	3.3
30 to 35 "	142	2.1
35 to 40 "	110	1.8
40 to 45 "	83	1.2
45 to 50 "	43	0.6
50 to 60 "	51	0.7
60 to 70 "	16	0.2
70 to 90 "	2	...
Unknown	520	8.0
	6,595	

*From 32nd Annual Report of the Managers and Officers of the Craig Colony, Sonyea, N. Y. (55).

year. The epilepsy of adults is usually senile and does not ordinarily develop until after the fortieth year. Exact determination of the beginning of epilepsy is frequently very difficult, because no adequate method of distinguishing epileptic seizures from the non-epileptic convulsions of infancy and early childhood has been devised. The general trend of the figures is, nevertheless, significant. Table II shows the age at which the disorder began in the 6,595 patients who up to 1926 had entered the Craig

TABLE III

Age Incidence of Epilepsy in 3,002 Cases*

Age	Number of Patients	Percentage of Total
Under 10 years	826	27.5
10 to 19 "	1,398	46.5
20 to 29 "	463	15.5

* From Gowers, W. R.: *Epilepsy and Other Chronic Convulsive Disorders*, 1901, 13.

Colony (Thirty-second Annual Report) (55). Only 25 per cent of the patients in that institution were free from the disease until they were twenty or more years of age. The data included in the table are confirmed by the observations of Gowers (108) who in 3,002 cases of epilepsy found the incidence highest between 10 and 19 years (Table III). Wilson (301) says that if idiopathic epilepsy does not develop before the age of twenty-one, the chance that it will appear subsequently decreases as each year passes. Stüchlik (272) in 1915 expressed the opinion that epilepsy tends to appear at an earlier age when there is an inherited taint.

Sex Incidence.—Females, according to many authors, are slightly less susceptible to epilepsy than are males, but there is some difference of opinion about this, and data have been accumulated which demonstrate the reverse to be true (Table IV). Patrick and Levy (222) say that at all ages the differential incidence in males is 60 per cent, while Gowers (108a) says that the proportion of males and females differs at different ages. His figures show

TABLE IV

Sex Incidence of Epilepsy

Author Quoted	Percentage	
	Males	Females
Gowers	48	52
Lange	55.8	44.1
Patrick and Levy	62	38
Binswanger	61.4	38.1
Berger	65.2	35.0
Morselli	46.	54
Spratling	60.1	39.9
Children's Hospital, Boston	55.5	44.6
Massachusetts General Hospital (1914-1926)	56.7	43.3

that before 10 years of age the incidence in females is 8 per cent above that in males; between 10 and 20 years the excess of females is 12 per cent; between 30 and 40 years the males preponderate by 19 per cent; between 50 and 60 years by 30 per cent; and after 60 years practically no females develop the disorder. Turner (289) states that the mean age of maximum onset is two years later in the female than in the male.

Statistics are still too fragmentary and unreliable to demonstrate whether the incidence of epilepsy

is falling or rising. Probably the rate has not changed markedly in relation to the total population, although as the world has become more populous there has undoubtedly been an increase in the total number of individuals who are subject to epileptic attacks. Increasing knowledge of disease has perhaps played some part in changing the apparent rate of incidence of epilepsy, for various conditions, which in the past may have been confused with this disorder, can now be accurately distinguished. There still remain, however, many points of diagnostic confusion, particularly in infants and young children. When these have been cleared away the incidence curve of epilepsy may be found to be quite different from what it now appears to be.

Occupation.—The occupation of individuals who develop epilepsy comparatively late in life appears to have no etiological connection with the occurrence of the attacks. There also appears to be no relationship between the occupation of the parents and the incidence of epilepsy in the offspring.

CHAPTER II

Etiology

Introduction.—In considering the syndrome known as epilepsy, all conditions which may cause the characteristic train of symptoms must be considered as possible etiological factors. This does not confuse the problem if epilepsy is regarded as a symptom and not as a sharply defined disease entity. Because the available data do not fall naturally into logical sequence, it seems best to consider the factors in the order in which they affect the individual and consequently the course of epilepsy. Heredity is, therefore, the first to be discussed. Next in sequence come injuries at birth, structural and general postnatal influences, and finally the degenerative diseases of old age.

Heredity.—Lengthy discussions of the effect of heredity on the incidence of epilepsy are to be found in the literature, and most textbooks give the impression that an hereditary factor surely plays some part in the etiology of the disorder. Examination of the various reports, however, reveals that the large mass of data has not been collected according to any uniform plan, and that selection for study of a disproportionate number of epileptics from institutions renders generalized conclusions invalid. Such

patients form a special class which in no way represents the entire epileptic population of a community.

It cannot be denied, however, that certain investigations seem to have revealed heredity to be an influential etiological factor. Davenport and Weeks (72) state that "Epilepsy and feeble-mindedness show a great similarity of behavior in heredity, supporting the hypothesis that each is due to the absence of a protoplasmic factor that determines complete nervous development." They have found that "When both parents are either epileptic or feeble-minded all their offspring are so likewise," and that "Normal parents that have epileptic offspring usually show gross nervous defect in their close relatives." These authors have also concluded from their field studies that there is an hereditary factor in idiopathic epilepsy which acts as a Mendelian recessive. They cite as illustration the conditions found on an island off the coast of Maine where the population is very much inbred and the incidence of epilepsy is high. It appears to be possible to trace the epilepsy back to the common ancestor of most of the inhabitants. Myerson (217) takes exception to the view that epilepsy is inherited as a Mendelian recessive and says, "the conviction is strong that epilepsy is mainly an affair of the individual and not of the stock; that it represents injury perhaps to a germ plasm, and certainly to the individual, whether that injury be pre- or post-natal." Thom (284) has made a study of heredity at the Monson State Hospital for Epileptics. Among the 1,536 records examined, he found useful data in 138 cases. Only 5.8 per cent of

the ancestors of these patients were epileptic, and among their 553 children only 0.55 per cent developed epileptic manifestations. At the time of the study, 328 of the normal children were over 20 years of age and therefore presumably free from the disorder; 225 others were still within the epileptic zone, *i.e.*, they were less than 20 years old. Later investigation of the children of another group of 117 individuals with idiopathic epilepsy (285) led Thom to conclude that an unstable nervous system and not epilepsy itself is the inheritable feature. He found that maternal defects are manifested in some way in the offspring more frequently than are paternal defects and that they tend to appear at an earlier age.

The influence of various genetic factors in epileptic patients has been tabulated by Flood (86) and may be of interest (Table V). In view of the great

TABLE V

INCIDENCE OF GENETIC FACTORS IN EPILEPSY *

	Alone	With Other Taints	Total	Direct Heredity	Collateral	Total
Epilepsy	44	44	88 57%	49	39	88
Alcohol	23	36	59 38%	58	1	59
Insanity	17	26	43 27%	24	19	43
Feeblemindedness .	3	13	16 10%	13	3	16
Migraine	9	27	36 23%	34	2	36

* Flood, E.: "Selected Statistics Concerning Epileptics Used at the Monson State Hospital in Illustration of Its Work, 1917," *Bull. Mass. Comm. on Mental Diseases,* July, 1918, 2, 94-107.

uncertainty of the etiologic rôle of heredity in epilepsy, however, it should not be given undue weight. That congenital syphilis may play an etiological rôle was suggested many years ago, but as the methods of diagnosis and treatment improve, syphilis is coming to play a progressively less important part in the picture. Only rarely is it now associated with epilepsy.

Birth Injury.—The importance attributed to the effect of birth injuries in the etiology of epilepsy is probably to be explained by the frequent development of epilepsy in individuals with severe infantile cerebral palsy. In the majority of instances this is the chief cause for associating the two conditions, for obvious epileptic symptoms do not usually appear during early infancy. Just what the true relation of the two disorders is has not yet been determined, although the subject has aroused much interest. Spratling (269) in 1904 said, "We are reasonably safe in stating that fully 40 per cent of all cerebral hemiplegias of infancy ultimately become epileptic" and attributes 11 per cent of his 1070 reported cases of epilepsy to infantile cerebral palsy. He quotes Osler as saying that 26 per cent of his patients with infantile hemiplegia developed epilepsy. Holt and Howland (122) in 1916 stated that epilepsy develops in between 33 and 50 per cent of all patients with birth palsies, but in 1927 made no mention of the etiological relationship of these two disorders. They merely say that "Convulsions in infancy that are followed by epilepsy are probably epileptiform from the beginning" (Page 556). Ford

(92) in 1926 gave 2-3 per cent as the proportion of epileptic cases which originate in birth trauma. Thus as our knowledge of epilepsy and birth injuries increases, the idea that the two conditions are closely interrelated becomes less tenable. It is probable that the after results of severe injury to the brain during birth do have a connection with the onset of epileptic seizures and depend upon the location, the severity, and the type of damage done; the effect of such damage must also depend upon the recuperating power of the individual as well as the type of treatment employed at the time of the original injury.

Trauma after Birth.—Other types of trauma, such as blows and gunshot wounds, have also been considered immediate and remote causes of epilepsy. The relatively low incidence of the disorder in soldiers who received head wounds during the Great War suggests, however, that the men who became subject to epilepsy were predisposed to it and might have become epileptic in any case. Sargent (250) reports that epilepsy developed in only 800 (4.5 per cent) of a series of 18,000 soldiers who received cranio-cerebral wounds with defects of the skull in the Great War, while Shanahan (261) states that direct violence to the head was the cause of epilepsy in 21 out of the 224 epileptics admitted to the Craig Colony for Epileptics during 1925. Poppelreuter (239) points out the possibility of a relationship between the height of blood pressure and the incidence of convulsions. He says that in a group of soldiers with head injuries, convulsions developed

only in those whose systolic blood pressure was over 135 mm. Hg. That there may be an interval of months or years between the time of injury and the onset of convulsions was noted by Putnam in 1892 (240). Turner (289) differentiates between the effects of injury to the head without obvious organic lesions and the effects of injury with organic lesion of the brain, skull, or membranes. Trauma of the first type may, in his opinion, be considered similar to emotional trauma; while injury of the latter type only can be considered to evoke true "traumatic epilepsy." He states that the fits directly due to trauma usually begin within a year of the time of injury and that in hemiplegic patients the convulsions affect the paralyzed side more severely. Latent epilepsy, he says, may be made manifest by injury, and the arrested condition may be recalled.

The etiological part played by whooping-cough is thought to be traumatic in nature rather than infectious. The paroxysms of coughing are in rare instances so severe as to cause cerebral hemorrhage.

Tumors.—Although the available data do not demonstrate the exact relationship between epilepsy and cerebral tumors they do show that epileptiform attacks are frequently associated with brain tumor and that in some cases at least the growth appears to be the cause of the symptoms. Turner (289) believes that the etiological rôle of cerebral tumors is greater than is generally thought, particularly when the epileptic symptoms begin in early adult life. It is probable, however, that only a small proportion of all cases of epilepsy are caused by these new growths.

Sargent (250), on the other hand, reports the occurrence of convulsions in 30 per cent of his 270 patients with brain tumor. Redlich and Pötzl (242) in 1910 stated that seizures are more frequent during the period when the tumor is too small to produce pressure, than they are in the later stages.

The location and type of the tumor determine in some measure the character of symptoms. A growth in the fronto-parietal region produces focal or general convulsions; in the temporo-sphenoidal regions, generalized fits and the uncinate attacks described by Hughlings Jackson (144). Tumors of the hypophysis act in two distinct ways: *i.e.*, by their physical pressure and by their influence on the endocrine function of the gland.

If cysts are not included in the classification of tumors, it seems fair to conclude that tumors play a very slight rôle in the etiology of epilepsy.

Cysts.—More and more of the surgeons who perform cerebral operations are coming to believe that there is some connection between cysts of the brain and epilepsy. Exactly what this is and whether or not the cysts are merely a peculiar manifestation of the "wet brain," which some consider more or less characteristic of epilepsy, is not known. Various hypotheses have been advanced, but none rest on a sure foundation. The relation of cysts to epileptic seizures will be considered later in the section on the use of dehydration as a method of treatment.

Infection.—From time to time there has been advanced a theory that epilepsy is caused by infection of the blood or intestinal tract with a specific organ-

ism. About 1902 there was published evidence in support of this theory. After that, enthusiasm waned until in 1916 Reed (243) and Terhune (283) reported that a specific *Bacillus epilepticus* had been isolated. Their work, particularly that of Reed, attracted the attention of various investigators and stimulated search for a bacterial cause of epilepsy. This led to no definite conclusions, but the bulk of evidence seemed to indicate that no specific infection of the blood stream and intestinal tract is the cause of epilepsy. Reed (244) after further investigation finally requested in 1917 that such of his "previous contributions as relate to the identity of a presumably specific organism and to the existence of an actual bacteremia in these cases may be considered as withdrawn" and makes "this request with apologies for what now seems to have been premature publication." He points out, however, that further bacteriological study of epilepsy may be helpful.

The frequent occurrence of certain chronic and acute infections in epileptic patients has suggested that perhaps these conditions may be one of the causes of epileptic symptoms. In some instances the infections attack the nervous system directly, in others they are generalized and exert only a secondary influence on nerve tissue. Just why convulsions should accompany certain types of infection is not known.

Syphilis, which at one time was thought without doubt to be responsible for certain cases of epilepsy, has been in some measure deprived of its previously assured etiological position by improvement in the

methods of diagnosis and treatment. It is, however, not infrequently coexistent with epilepsy. Tuberculosis is another chronic infection of the central nervous system which is commonly associated with convulsive seizures.

Among the acute infections under suspicion, the most important are encephalitis, meningitis, scarlet fever, otitis media, mastoiditis, and brain abscess. Out of the 135 cases of encephalitis studied by Osler and McCrae (220) 41 were followed by epilepsy. The convulsions associated with these conditions usually appear during the febrile stage. Measles, enteric fever, and chorea are less often accompanied by epileptoid manifestations, but are occasionally followed by recurrent attacks of unconsciousness or convulsions. The effect of whooping-cough is supposed to be quite different from that of the other infections, for the seizures which sometimes follow it are thought to result from trauma inflicted by the paroxysms of coughing rather than from the infection *per se*.

With the evidence at hand one is forced to the opinion that infection plays only a minor rôle, if any at all, in the etiology. Such relation as it has is apparently not due to the action of the bacteria or their toxins, but to the immediate or late effects on the cells of the central nervous system. Statistically, infection stands in about the same place as an etiological factor as does tumor.

Intoxication.—Almost as little is known about the mechanism by which the various toxins might evoke epileptiform symptoms as is known about the

action of the infections. There seems to be a strong conviction, however, that certain substances can be either responsible for, or contributing factors in, the development of epileptic seizures. Alcohol is the first of these to be mentioned, partly because it is so generally used, and partly because its effects are thought to be especially pernicious. Two quite separate types of injury are attributed to it: *i.e.*, injury to the individual who indulges in its use, and injury to the germ cells produced by that individual during periods of indulgence. Evidence to support these hypotheses is so unsatisfactory that statements regarding the effect of alcohol can be hardly more than suppositions. They are, however, worth including here. Statistics showing the incidence of epilepsy in regions where alcohol is and is not freely used are quite contradictory. Davenport quotes Hrdlicka (127) as saying that among the Otomi Indians who drink to excess, "epilepsy and other neuropathic conditions are met with frequently." But Davenport (73) also reports that among the Mussulmans, who are forbidden to use alcoholic liquors, epilepsy is an important cause of death. The statistics given for Kansas and other sections of the United States where there are large numbers of Mormons who use no alcohol, would lead to the reverse conclusion. Sioli comments on the temperance and the low incidence of epilepsy among the Jews. If now the problem is looked at from another angle and the occurrence of excessive drinking among epileptics is considered it will be found that the proportion of patients who indulge immoderately in alcohol is quite small.

Shanahan (261) says that among the 224 patients admitted to the Craig Colony in 1925, there were only 3 whose epilepsy could be ascribed to alcoholism. Alford and Schwab (5) give a higher proportion; 6 out of 80 cases; and Küffner (159) in 1927 reported that in his group of 2000 patients the epilepsy and excessive drinking were associated in 8 per cent of the men and 1.3 per cent of the women.

Our information concerning the relationship between alcoholic excess in the parent and the development of epilepsy in the offspring of the next or succeeding generations is highly unsatisfactory. Turner (289) states that parental alcoholism predisposes to epilepsy, and Zabriskie (306) says that according to Barrett "alcoholism occurs in 25.89 per cent of the antecedents of epileptics."

About one point there is comparatively little uncertainty. In individuals who are subject to epileptic seizures, the excessive use of alcohol may be the immediate cause of attacks. Some authors make an even broader statement than this and say as does Turner (289) that "alcoholic intoxication induces in predisposed persons a form of eclampsia, or acute epilepsy." This type, in his opinion, is "rarely followed by epilepsy of the usual chronic type, the fits ceasing under treatment, when alcohol is no longer taken, but returning with a relapse into alcoholic excess." Turner mentions, however, "a chronic form of epilepsy—in chronic alcoholism" and remarks that "in countries where absinthe drinking is prevalent, absinthe epilepsy is stated to be of frequent occurrence."

Such evidence, therefore, leads to the conclusion that whereas alcohol is bad for patients suffering from seizures and should not be indulged in, there is no definite indication that it is, *per se,* the fundamental cause of epilepsy.

Lead is another substance which is thought to be capable of evoking epilepsy under certain conditions. Not all authors consider it sufficiently important to merit discussion, but most modern textbooks contain some reference to its possible relationship to epilepsy. Oppenheim (219) says that epileptic symptoms may develop during chronic lead poisoning. Block (37) states that "chronic lead poisoning in the parent sometimes produces epilepsy in the offspring." And Aub has pointed out (13) that fatigue increases the susceptibility of lead-poisoned guinea pigs to convulsions. It should always be considered among the remote possible causes of seizures.

The epileptiform symptoms which are sometimes ascribed to uremia support the view that epilepsy is a symptom and not, *per se,* a disease entity. When seizures occur in a uremic patient they are but manifestations of the renal disease which causes the uremia. Since it has become customary to consider "epilepsy" the group of symptoms for which no definite cause has been found, uremic convulsions are not commonly discussed in connection with true epilepsy.

Hydrocephalus.—Hydrocephalus can hardly be considered a cause of epilepsy. In the rare cases when the two conditions occur together it is, rather,

comparable to the epileptic manifestations in being an evidence of some more fundamental disorder.

Disorders of the Gastrointestinal Tract.—There is little doubt that disorders of the gastrointestinal tract so influence the bodily economy as in some way to favor the development of epileptic attacks in predisposed individuals. That they are not an all-important primary factor in the causation of epilepsy is also certain, however, for the two types of disturbance very frequently develop independently. Those who have supported the idea that the gastrointestinal tract alone may be responsible for the development of epilepsy believe that constipation, stasis, ptosis, dilatation of the cecum and colon, *et cetera*, alter the processes which normally take place in the alimentary canal in such a way as to favor the formation or absorption of toxic substances. These poisonous materials are thought to result from abnormal decomposition of food in the alimentary canal or from bacterial action. Caro (45) in an attempt to correlate epilepsy with abnormalities of the gastrointestinal tract found adhesions and peritoneal bands in 18 per cent of 280 institutional patients at autopsy. This is approximately the same incidence of these defects as was observed at 775 autopsies of non-epileptic patients at the Boston City Hospital. The natural conclusion is, therefore, that the constipation of epileptics arises from the same causes as does that of other individuals.

Glands of Internal Secretion.—Because of their far-reaching and little understood effects the glands of internal secretion have been held responsible,

from time to time, for most of the obscure diseases of man. Of the various attempts made to explain epilepsy by means of their dysfunction, most are not worthy consideration. A few careful scientific studies have been made, however, which demonstrate that in individual instances these glands may be in some way related to the epileptic manifestations. Lind (190), on the other hand, in 259 autopsies found no evidence that changes in the endocrine glands are the cause of epilepsy. Engelbach (83) says that in his clinic "only about 2 per cent of 'epileptic cases' were definitely related to endocrine disorders and relieved by endocrine treatment."

Gonads.—As a result of the fact that it is not uncommon for the recurrent convulsive attacks of childhood to cease at puberty or during early adolescence, an etiological rôle has been attributed to the gonads by many observers. Those who enthusiastically support this view have not taken into consideration the large numbers of patients whose epilepsy begins during childhood and persists throughout adult life. There is little likelihood that the gonads exert more than a very slight influence on the course of epilepsy. The disappearance of the seizures at the time of puberty, the onset of epileptic attacks in early adolescence, and the epileptic changes which occasionally take place at the time of the menopause are probably not direct effects of gonadal activity. An effort has been made to explain the periodicity of attacks in adult women by relating them to the menstrual periods, but there seem to be no well-authenticated facts to support

this theory. Among savage people the periodicity has been explained by the influence of the moon.

The effectiveness of gonadal medication has not been established.

The Pituitary.—The endocrine gland which has received most attention in relation to epilepsy is the pituitary. This body is so situated that if it became enlarged or were the site of a tumor its mechanical action might profoundly affect the function of certain parts of the brain. Epilepsy resulting from such abnormalities could hardly be considered of endocrine origin, however, for it would be entirely independent of the secretory activity of the gland, unless, as Cushing suggests (61), the presence of the enlargement "blocked" its endocrine activity. Cushing (61) says that "Clinical states of diminished glandular activity which are associated with tumor may be due either to an actual loss of glandular tissue from partial destruction by an infectious or malignant growth, by vascular disease, hemorrhage, cyst formation, or what not," and points out that "of great importance is the relationship between certain types of epilepsy and states of hypopituitarism" (61). In 1910 Crowe, Cushing, and Homans (56) reported that after removal of the posterior hypophyseal lobe of a dog, peculiar convulsive attacks ensued with maniacal excitement. This work supports Cushing's belief that, in certain instances, epilepsy is associated with pituitary insufficiency. In 1912 (60) he cited the cases of seven patients with hypopituitarism who were subject to unmistakable uncinate gyrus seizures. Six others are mentioned

who had general epileptiform attacks without features referable to the uncinate gyrus. Five of these subjects were supposed to have had primary glandular hypoplasia. Cushing's evidence in favor of a possible relationship between epilepsy and the pituitary may be summarized as follows:

> The cortex of hypophysectomized animals is unusually excitable on stimulation. Epileptiform convulsions occur in partially hypophysectomized animals which manifest symptoms of glandular insufficiency. Epilepsy in man is frequently associated with clinical evidences of pituitary insufficiency. It is also a common sequel of the types of cranial injury in which the pituitary is liable to be damaged.

Horrax's observation (124) that hypoactivity of the pituitary may result from intracranial pressure suggests that under some circumstances reduced activity of the gland may be secondary and not, *per se*, the primary reason for the symptom complex. Tucker (288) reported in 1919 that in only 14 per cent of his group of 200 epileptics could the abnormality be referred to the pituitary alone. Leahey (160) believes that there is a definite relationship between hyposecretion of the hypophysis and epilepsy, but states that practically all his patients showed signs of pluriglandular involvement. That transitional forms of endocrine disorder should be looked for in every case of epilepsy seems to him desirable.

Anatomical studies of the pituitary in epileptics have also given contradictory results. Johnston (148) reports that in patients whose epilepsy (petit mal) begins between 15 and 35 years of age the

topography of the sella turcica is regularly abnormal and that the size of the fossa is diminished. He also found changes in the skull resembling those of acromegaly. These and other observations, he feels to be justification for the conclusion that "epileptoid seizures are wholly or in part the result of the deprivation of the animal economy of those substances necessary to metabolism and produced within the pituitary." This conclusion is directly opposed to that of Munson (213, 214). This observer reports that there were in his cases no constant changes in the anatomy of the pituitary; and that a possible diminution in the size of the gland and occasional enlargement of the sella turcica are the most striking signs of pituitary disorder in epilepsy.

In spite of the many careful studies that have been made, data are still too contradictory to permit the formulation of satisfactory conclusions. About all that can be said is that there seems to be a relationship between pituitary function and *some types* of epilepsy. It is not even clear which condition is primary and which secondary. The results of administration of pituitary substance are of little conclusive value, for most of the data collected are poorly controlled or too meager to permit generalization.

Thyroid.—The numerous reports of the effect of thyroid therapy in epilepsy are evidence that there has been much interest in the relation between this gland and the syndrome of recurrent convulsive attacks. The data given are, however, highly unsatisfactory. Some authors state that administration of

thyroid preparations has brought great benefit, others that it has been of no therapeutic value, and still others that it has been harmful. The fact that the basal metabolism (see page 144) is below normal in about 12 per cent of the cases reported might be taken as evidence that a proportion of the cases are hypothyroid. This conclusion, however, cannot have unqualified acceptance since other factors have a definite influence on the basal metabolic rate. The clinical test of thyroid therapy in these cases is usually disappointing. Occasionally brilliant results are obtained as in Joslin's case (152) of a child.

Parathyroid.—Parathyroid insufficiency lowers the calcium content of the blood and increases the irritability of the nerves. Consequently symptoms of tetany ensue. These may sometimes so resemble the symptoms of an epileptic attack as to render differentiation difficult, and it is probable that the connection which has been supposed to exist between hypofunction of the parathyroids and epilepsy is merely a sign that tetany and epilepsy, two entirely unrelated disorders, have been confused. Bisgaard (36), however, connects dysfunction of the parathyroid with epilepsy and states that administration of the parathyroid hormone benefits the patient. Madsen (199) asserts that Collip's parathyroid extract reduced the number of attacks and improved the psychic condition of 3 out of 5 epileptics. This is not, of course, proof that there is parathyroid insufficiency in epilepsy. Volland (293) in 1910 reported that in 24 epileptic necropsies, abnormality of the parathyroid was observed only once. Since de-

ficiency in the parathyroid hormone is accompanied by a lowered blood calcium, it is reasonable to include among the possible parathyroid deficiencies only those cases with this chemical finding. In the author's experience this occurs very rarely in children. It is possible that it may be more frequent in adults, but no conclusive data are available.

Adrenals.—Data have not yet been accumulated which demonstrate a definite relationship between the adrenal glands and the etiology of epilepsy, although this question has aroused much interest. Benedek (25) found that injections of 1 to 1.5 c.c. of adrenalin were followed by typical seizures in 7 of 19 epileptics. Bertolani (32), however, considers that the occurrence of seizures in 3 of his 48 epileptics after the administration of adrenalin in doses of 3 c.c. or less cannot be attributed to the effect of the adrenalin. Cobb (180) reports that in his experience epileptic seizures sometimes follow subcutaneous injection of adrenalin, but that in 21 instances he has injected adrenalin without precipitating an attack. After reviewing many publications he concludes that adrenalectomy does not prevent seizures in man. The work of Popea and Eustatziu (237) suggests that the adrenals may be involved in some way by epileptic seizures, for they have found almost complete absence of lipoid material in the adrenal cortex of two patients who died in status epilepticus. These findings can be explained equally well as a result of the intense work performed. Volland, on the other hand, (293) observed adrenal abnormality only once in a series of 40 autopsies on epileptics.

Pancreas.—The coexistence of epilepsy and diabetes is so rare that it hardly seems possible that the two conditions can depend upon any common etiological factors. Their character differs so fundamentally that it seems far more probable that there might be features in one disorder which would be curative for the other and vice versa. For example, in diabetes there develop ketosis and other metabolic disturbances which appear to reduce the severity of epilepsy. Elliott P. Joslin (152) writes "that among 5,091 true diabetics whom I have seen there has been no case of epilepsy."

Summary.—About all that investigation has demonstrated in regard to the connection between epilepsy and the various endocrine glands is that usually there is no relation between the symptom complex and endocrine disorder, and that whenever there is a relation it is probably secondary and not the cause of the epileptic manifestations.

Anaphylaxis.—Because anaphylaxis is sometimes accompanied by convulsive symptoms it has come to be connected with epilepsy in the minds of some writers. Howell (126) outlines the histories of 14 patients who were sensitive to various substances or who had seizures after eating certain foods. He felt that in three instances anaphylactic therapy arrested the epileptic symptoms. Miller (209) has suggested that epilepsy must be a sensitization disease because it is usually less severe after infection. The disappearance of seizures in some women during pregnancy he explains as the result of desensitization to

a foreign protein, *i.e.,* the placenta. In his opinion evidence of non-specific desensitization has been found. Recently, Ward and Patterson (296) have studied the sensitiveness to protein of 1000 epileptics in institutions and compared their results with similar observations on 100 non-epileptic individuals. They report that 37 per cent of the patients who were at Craig Colony and 56.8 per cent of those in the New Jersey State Village for Epileptics were sensitive to the raw protein extracts employed. Only 8 per cent of the non-epileptic subjects reacted positively. Contradictory evidence is to be found, however, in the work of Cohen and Lichtig (51) and in observations made in the Children's Clinic of the Massachusetts General Hospital. Cohen and Lichtig report that in the families of 250 patients with asthma there was not an abnormally high incidence of epilepsy; and that they could find no relationship between convulsive symptoms and the reaction of 10 epileptics to proteins to which they were sensitive. The data accumulated by Ward and Patterson suggest the possibility of a connection between epilepsy and anaphylaxis, but do not constitute adequate proof of its existence. Rackemann (241) in a series of 3000 cases of suspected allergy seen during the last ten years has found a very low incidence of epilepsy. Two adults who were thought at first to be epileptic proved to have brain tumors. One boy of 17 years had epilepsy, tuberculous lymph nodes, Hodgkin's disease, and typical rag-weed hay-fever. One child of two, who had suffered from convulsions for a year, reacted positively to skin tests for cod-

fish and mackerel. None other of his patients exhibited symptoms of epilepsy.

Evidence seems, therefore, to indicate that whatever relationship there appears to be between the two conditions is accidental and not of etiological significance.

Psychology.—Recent advances in the understanding of functional psychology have revealed such great possibilities that many writers have yielded to the temptation to explain all abnormalities by the existence of psychic disorders. This, of course, has been very unwise and has added unnecessary confusion to an already complicated problem. Just what the connection may be between psychic and physical disturbances has been determined only in rare instances. There is little doubt, however, that psychology can at times play an important part in the production or persistence of disease. That psychic disturbances and epilepsy are quite closely related would probably be denied by very few people who are familiar with the manifestations of epilepsy. The exact nature of this relationship has, however, not yet been determined. In certain cases psychic trauma seems to have been responsible for the onset of epilepsy, but there is no definite proof that some physical change had not taken place before the psychic shock was received. Fright and mental strain have for many years been known to be distinctly harmful to epileptic patients and to be capable of inducing attacks in certain of these individuals. On the other hand, it is also known that epilepsy is sometimes secondary to dementia præcox. Until more can

be determined about both the physical and the psychological nature of epilepsy no conclusions can be drawn concerning the relative importance of these two etiological factors. It is my own belief, however, that in certain cases the psychological factor is of little or no importance in the causation of epilepsy, that in the majority of cases physical and psychic factors are closely interwoven, and that in a certain number of instances the seizures are almost entirely due to psychic causes. Sufficient data are not yet available definitely to confirm this belief, but there are many indications which point toward its veracity.

Changes in the Reaction of the Body Fluids.—The theory has been advanced that a shift of the acid-base equilibrium of the body toward the alkaline side may be a factor in the causation of epileptic attacks. Jarloev (146), in 1921, reports that the blood of individuals subject to epilepsy is more alkaline than normal; and Mørdre (211) and Dautrebrand (71) show that the alkaline reserve of epileptics is very large. According to Bigwood (34), on the other hand, the hyperalkalinity of the blood in epilepsy is not due to accumulation of bases, but to a breakdown of the mechanism which regulates the reaction of the blood. An unusual variability of the ammonia content of the urine and blood of epileptics has been pointed out by Bisgaard (35) and Hasselbalch (112). Geyelin reports that "there is no pH curve definitely characteristic of epilepsy, but it may be said that the blood of epileptics shows a distinctly wider range of pH from day to day and from

hour to hour than does the blood of normal persons" (106). Lennox's work (172) on the effect of the ingestion of NH_4Cl and $CaCl_2$ on epilepsy has demonstrated that such treatment produces a marked temporary reduction in the frequency of seizures, but that in the few instances in which the ingestion of these salts was continued, many small seizures ensued at the end of a week or ten days. Evidence is still too incomplete to demonstrate how far outside the possible limits of normal these epileptic variations lie, and no satisfactory conclusion can be drawn about their relation to the development of symptoms until further investigation has been carried out.

Tetany.—Although it is well known that in some types of tetany the acid-base equilibrium of the tissues characteristically shifts toward the alkaline side, observers agree pretty generally that tetany and epilepsy are quite separate syndromes. It is conceivable, however, that exaggeration of the hyperalkalinity reported to be associated with epilepsy might result in tetany with alkalosis.

Cerebral Anemia.—During the meeting in New York City in December, 1929, of the Association for the Study and Prevention of Nervous and Mental Diseases, much attention was given to the possible relationship between cerebral circulation and the occurrence of seizures. At the meeting (11) Gildea and Cobb presented experimental evidence that cerebral anemia may be of importance in inducing attacks, and Speilmeyer showed that changes in the cerebral circulation are closely related to seizures in human beings. Patterson stated that at the beginning of at-

tacks it is impossible to find the small cerebral arteries and that the veins may collapse. Olkan, who has studied the problem from the physiological point of view, concluded from his data that epilepsy is attributable to a vasomotor disturbance of the capillaries.

Wet Brain.—The theory that accumulations of fluid in or on the surface of the brain, which has recently assumed prominence, will be considered in detail in the section on dehydration.

Reflex Irritation.—For many years epilepsy has been attributed to the effect of localized irritation such as that produced by intestinal parasites, defective vision, impacted or carious teeth, adherence of the prepuce, and other chronic disturbances. The brilliance of the recovery which occasionally follows removal of these irritations has apparently given undue weight to their etiological effect, for it is the rare exception and not the rule for them to be the primary cause of epileptic attacks. Most investigators who have studied the available data feel that these reflex irritations play at most but a very insignificant secondary rôle in the development of epilepsy.

Arteriosclerosis.—A syndrome, seen in elderly individuals, so closely resembles epilepsy that differentiation is often practically impossible. The symptoms which are caused by arteriosclerosis appear when the brain is deprived of blood because of poor circulation or when there are minute hemorrhages in the cerebral tissues. Whether or not convulsive seizures of this type can correctly be considered epileptic in

character is a moot question. The majority are undoubtedly merely the result of arteriosclerosis.

The foregoing discussion of various possible causes of epilepsy demonstrates very clearly that the fundamental cause of the disorder has not yet been recognized. With increasing knowledge, the correct relative importance of the factors which are thought to be reponsible for epileptic manifestations can undoubtedly be determined, so that those which are primarily responsible for the syndrome can be distinguished from those which exert merely a secondary effect. When this has been accomplished there is little question but that a few at least of the causes usually enumerated will be scratched off the list.

CHAPTER III

Pathology

There is no proof that any given lesion is responsible for the development of epilepsy, but certain abnormalities have been reported to appear with unusual frequency in individuals subject to recurrent convulsive attacks. The lack of uniformity in the appearance of these lesions, however, is evidence that the majority must be merely incidental or at most but secondary manifestations. Increasing knowledge seems to strengthen the hypothesis that a physiological rather than an anatomical lesion may be primarily responsible for the convulsive seizures of epilepsy, but proof is still lacking for even this general statement.

Since epilepsy has been recognized to be a symptom of certain disturbances and not, *per se,* a disease entity, observers have come to appreciate that whatever abnormality primarily induces the convulsive attacks must be of a very fundamental nature, for it is associated with varied and superficially unrelated conditions.

The number of anatomical lesions to which convulsions have been attributed is remarkably large. The brain and spinal cord of epileptics have been repeatedly examined, of course, and many of the

lesions discovered have been thought to be specific by the various observers. No one has yet identified a defect, however, which can be consistently demonstrated at autopsy in epileptic patients by all investigators. Whether or not there may exist a defect which is apparent during life and so slight or of such a character as to escape notice after death is a question which has been raised by brain surgeons. Dandy (66) has observed that before or during operation the "changes that one finds are: (1) dilatation of the ventricles, (2) abnormally shaped ventricles, (3) dilatation of the subarachnoid spaces, (4) softening of the brain (atrophy), (5) areas of increased density (fibrosis or gliosis), (6) changes in the meninges." He states that "It is mainly at operation that dilatation of the subarachnoid spaces is demonstrable. After death the fluid quickly disappears, and particularly after the brain has hardened this indicator is to a large extent lost. When very marked it can still be made out even after fixation, but there is never the striking appearance, postmortem, which is present in the brain at operation. One of the great advantages of inspecting the brain at operation is the comparison of its volume with that of the intracranial cavity. There is hardly anything more striking than the collections of fluid which cover the surface of the brain of the epileptic. They stand out almost as sharply as tumors on the surface of the brain." In 1927, four years after publishing this statement, Dandy (69) reported that, in his opinion, "The reason for the absence of a striking pathological picture at necrospsy is - - - that the

lesions of the brain which cause epilepsy have long since passed their acute stage; and in healing these lesions nature has healed so perfectly that very little remains to be seen either in the gross or microscopic examination." Fundamentally epilepsy, in his opinion, is due to an organic change or lesion in the brain. In this later article he discusses the work of Alexander in England on the significance of the pools of subarachnoid fluid in epileptics and mentions data which lead him to the conclusion that they are the result and not the cause of epilepsy. Temple Fay (84), on the other hand, emphasizes the importance of pathological data observed during life. He draws attention to the importance of "the histopathological findings of a cortical film of gliosis and thickening of the pia-arachnoid as well as subarachnoid collections of fluid, edema, and increase in size of the cerebrospinal fluid pathways." Weed and Hughson (297), he says, "have shown that the cranium and spinal canal may be considered a 'closed box' after the age when the sutures have united. This closed spinal fluid system, according to the Monroe-Kellie doctrine, must follow the laws of hydrodynamics, as long as the pathways remain open and communicating, thus, 'pressure exerted at any point within a closed fluid system is equally distributed to all points throughout the system,' would seem to apply." "It therefore seems probable that the soft tissues of the brain, caught between periodic and long-standing attacks of such pressure, might undergo atrophy of this type, either due to the direct influence of the pressure, or the secondary effects of

this pressure upon the small capillaries." He presents as an explanation of increased pressure the theory that the arachnoid villi are concerned with the escape of cerebrospinal fluid into the dural venous sinuses, and that pathological changes in them and more particularly the pacchionian bodies can interfere with the escape of fluid from the cerebrospinal system in a manner similar to the interference with the escape of fluid from the body when there is damage to the glomeruli of the kidney. Although the pathology of this conception of epilepsy has not been convincingly demonstrated, the theory of it has been described in some detail, because upon it is based the dehydration method of treatment which is described later. In a very full review, Lennox and Cobb (180) have recently published a critical discussion of the existing observations on the physiology and pathology of the central nervous system with especial reference to epilepsy. This should be consulted by any one particularly interested in the pathology of epilepsy. The subject is far too involved to be discussed fully here. Careful consideration of the data, however, will show that there is little doubt that some disturbance in the brain lies near the root of certain types, at least, of epilepsy. There is also good reason to suppose that the presence of excess fluid in the subarachnoid space may play a large part in the production of attacks.

The search for epileptic lesions has not been restricted merely to the central nervous system. Many investigators have studied other parts of the body in the hope of finding abnormalities which might

account for the apparently nervous symptoms. Some students attribute epilepsy and the advent of seizures to the existence of intestinal adhesions and peritoneal bands; others feel that morphological and chemical changes in the blood and spinal fluid play the causative rôle; and still others have attributed the seizures to hypertension of the blood and spinal fluid, to infections of various sorts, particularly syphilis, and to endocrine disorders. No data have yet been obtained, however, to demonstrate that such abnormalities are more common in individuals subject to epileptic attacks than in those who are not. What few indubitable facts we have seem to indicate that the fundamental disorder of epilepsy is of such a character that it affects all parts of the body.

CHAPTER IV

Diagnosis

The consideration of the diagnosis of epilepsy differs with the point of view and training of the examiner. If his work is primarily with children, it will be unnecessary to warn him that the majority of convulsive seizures in infants and young children are non-epileptic, while if he is caring mainly for adults, he will look for syphilitic infection, evidence of arteriosclerosis, brain tumor, and chronic nephritis as causes of the convulsion.

In all cases the age factor should be given consideration and the final diagnosis be influenced by it.

Examination of the Patient.—In differentiating epilepsy from other apparently similar conditions, factors of so many types must be considered that familiarity is essential not only with the full medical history of the patient but also with his intimate surroundings and with the problems of his daily life. For a specialist this is often difficult or impossible to acquire without coöperation from the family and the attending physician, but no record can be considered a satisfactory basis for the diagnosis of epilepsy unless it includes at least a general description of the personal interests and handicaps of the patient. Because the details which are relevant for different in-

dividuals appear to be quite dissimilar, no rule of thumb can be given for obtaining the necessary information. Only by his own astuteness and patience can the doctor in charge discover whether the pertinent non-medical data are associated with business, family conditions, or social relationships. Usually the salient facts can be obtained from the patient or from some member of the immediate family, but occasionally it is an understanding friend or relation who points out the really important personal considerations. Factors which assume great weight in the minds of the patient's close associates may be of little significance to the patient himself and be correctly evaluated by observers with more perspective. Since the reverse is also true, a doctor who would be successful in dealing with epileptics must be a keen judge of human nature and human relationships.

The routine physical examination to be given when there is any suspicion of epilepsy should be sufficiently detailed to reveal even minor abnormalities. Particular significance is to be attributed to certain of the data usually obtained in a general physical examination and additional information must be gained by specially trained observers.

Since *posture* may intensify otherwise slight disorders, and itself be affected by co-existent disturbances, it should be carefully noted. Records made at intervals often reveal significant changes. Unless great accuracy is desirable the standards used at Harvard University (Figure I) prove satisfactory.

Cytological examination of the blood greatly facilitates differential diagnosis by demonstrating the

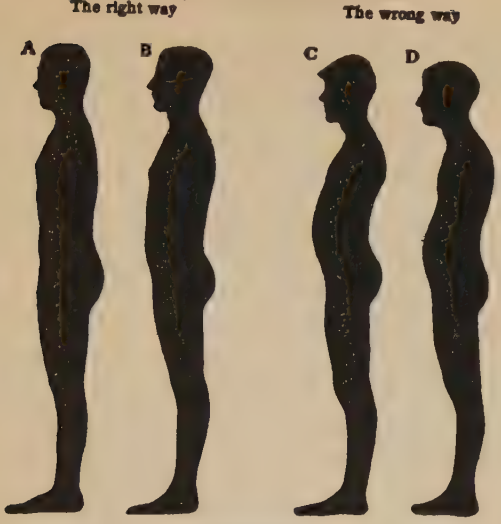

FIGURE I.

Postural Standards Used at Harvard University.*

(A) Excellent Mechanical Use of the Body

1. Head straight above chest, hips and feet.
2. Chest up and forward.
3. Abdomen in or flat.
4. Back, usual curves or not exaggerated.

(B) Good Mechanical Use of the Body
(Compare with Fig. A)

1. Head too far forward.
2. Chest not so well up or forward.
3. Abdomen, very little change.
4. Back, very little change.

(C) Poor Mechanical Use of the Body
(Compare with Fig. A)

1. Head forward of chest.
2. Chest flat.
3. Abdomen relaxed and forward.
4. Back curves are exaggerated.

(D) Very poor Mechanical Use of the Body
(Compare with Fig. A)

1. Head still farther forward.
2. Chest still flatter and farther back.
3. Abdomen completely relaxed, "slouchy."
4. Back, all curves exaggerated to the extreme.

* Prepared and issued by the Department of Hygiene and Physical Education, Harvard University, Cambridge, Mass. Used here by permission.

anemia and polycythemia associated with certain non-epileptic conditions. *Chemical analysis* often reveals anomalies characteristic of other disorders than epilepsy. Convulsions which occur, for example, when the calcium content of the blood is below 8 mg. per 100 c.c. are probably due to spasmophilia but may, especially in adults, be related to the parathyroid gland. The carbon dioxid content is relatively great after over-ventilation of the lungs and a high combining power is considered evidence of alkalosis. *The Wassermann reaction of the blood* of epileptics is positive no more often than that of other individuals, but when it is positive this fact should be given due consideration and appropriate specific treatment should be instituted. *Blood pressure,* particularly in older patients and when the possibility of eclampsia must be considered, may be very significant.

Endocrine disorders have not yet been proved to be closely related to epilepsy, but they deserve special attention. For this reason watch is to be kept with particular care for any signs indicative of the need of further study. Despite lack of conclusive evidence that the thyroid is involved in the epileptic condition, basal metabolic tests are desirable when there is even a suggestion of its dysfunction. These, of course, require special apparatus and technical training. Signs of pituitary dysfunction should be especially looked for and treated when possible.

Among other special tests to be carried out are those in the *neurological examination.* Certain significant paralyses, sensory and motor disturbances,

and reflex anomalies can be detected only by a skilled neurologist; and other signs which might facilitate localization of the seat of trouble almost invariably escape the notice of a physician without unusual neurological training.

Evidences of intracranial pressure in the eye-grounds are detected by ophthalmoscopic examination which can be confirmed, if necessary, by an *oculist.* They should be looked for at intervals until diagnosis is assured, so that increases of pressure will not pass unnoticed. Errors in refraction may also be found with sufficient frequency to justify examination by a specialist.

More than a cursory glance must be given the *teeth.* A competent dentist should look for any defects which might prove irritating, and a Roentgen ray examination should be made if there is suspicion of abscess formation at the roots or of impaction. The importance of such examinations increases with the age of the patient. In adults they should never be neglected.

It is also advisable to make a thorough X-ray examination of the *skull,* so that possible fractures and tumors will not be overlooked. Evidence of increased intracranial pressure and of infection in the sinuses may be found in the same plates.

In most cases X-ray or fluoroscopic examination of the *gastrointestinal tract* after ingestion of a barium meal reveals nothing abnormal, but in a few patients functional or developmental anomalies can be found which are injurious to the general health. These cannot be considered, however, to be of prim-

ary importance in the epileptic syndrome, as they appear with no greater frequency than in the normal individual.

Many authorities recommend *lumbar puncture* as a diagnostic procedure in epilepsy. It permits measurement of the spinal fluid pressure and its response to jugular pressure. Analysis of the spinal fluid itself does not usually prove worth while, but occasionally valuable data are to be found in the cell count, the gold sol and Wassermann reactions, and the total protein content.

Ventriculography has now been used in a sufficient number of cases so that its dangers and the benefit of such an examination are understood. It is of very distinct value in indicating the position of lesions and in mapping out the various parts of the brain. It is said to be about as dangerous to life as is appendectomy and should be carried out only in a hospital.

Diagnosis.—In the diagnosis of epilepsy physicians should remember that the stigmata of the disorder must not be placed on an individual until all doubt has been removed. It is therefore essential to weigh all factors in the balance and to be certain that the symptoms observed are not an unusual manifestation of some other condition. In distinguishing between the various types of fits and in determining their cause the importance of the history of the patient and the details of the attack is as great as that of the results of the physical examination and the laboratory tests. It is unfortunate that the physician must frequently form his opinion on

data provided by the patient and his associates rather than on facts obtained by direct observation. Rarely can a doctor see his patient during an attack. Recognition of the major attacks (grand mal) after the disorder has become well established is usually not very difficult, but the minor attacks (petit mal) and the seizures that occur at the onset of epilepsy are often diagnostic puzzles. Definite conclusions can never be drawn until the patient has been watched for some time and seizures have been repeated. Unless the symptoms are repeated they cannot be said to be epilepsy.

Major attacks that can be observed throughout are in most cases easily recognized, for although the details differ in each patient the seizures all follow about the same course. If the attacks occur at night, when the patient is alone, satisfactory data are difficult to obtain, but it is possible to base diagnosis on the initial cry, the bitten tongue and blood-stained saliva, the urinary and fecal incontinence, and the headache which follows the seizure.

Minor attacks are more varied in character and consequently more easily confused with other conditions. They usually begin with pallor, staring of the eyes, dilatation of the pupils, loss of consciousness, and peculiar movements of the head, neck, or extremities.

Symptomatic seizures, i.e., those for which there is a specific known cause, can be differentiated from the other types by means of data obtained in the physical examination and laboratory tests. *Jacksonian epilepsy,* which falls under this head, has sev-

eral distinguishing features. Consciousness is never lost during the seizures, the convulsions are restricted to definite groups of muscles, there is lack of tonic spasm, and in each patient the attack begins or has at one time begun with definitely localized symptoms.

Differential Diagnosis.—Convulsions which occur during the first week or ten days of life are for the most part due to *cerebral hemorrhage*. This may, if it is sufficiently extensive, cause hemiplegia and subsequently lead to epilepsy (in about 50 per cent of cases), but convulsive symptoms which develop immediately after birth cannot be considered epileptic in nature. *Spasmophilia* and *tetany* are sometimes difficult to distinguish from epilepsy during infancy, but the true character of the symptoms can usually be demonstrated by determination of the calcium content of the blood, the number and repetition of the attacks, and careful consideration of the time of onset. In epilepsy there is usually no change in the blood calcium concentration, and symptoms do not ordinarily begin until after the patient is three years old. In spasmophilia, on the other hand, the quantity of calcium in the blood is subnormal and convulsions occur most frequently during the first twelve to eighteen months of life. Changes in the electrical reactions (Erb phenomena) and in Trousseau's and Chvostek's signs are positive evidence of infantile tetany.

If attacks begin suddenly without warning, the possibility of *tumor* must always be considered. Positive evidence of new growths is often difficult

to obtain in the early stages, but in later childhood and in adult life symptoms of pressure and characteristic changes in the eyegrounds are to be found. *X-ray* plates of the skull, ventriculography, and neurological examinations may also provide conclusive data.

Differentiation between petit mal and *fainting* is often very difficult, although fundamentally the two conditions are probably quite dissimilar. Fainting ordinarily begins less suddenly than petit mal, is not accompanied by convulsive movements, is associated with contraction rather than with dilatation of the pupils, and never causes involuntary passage of urine. Recovery is prompt after the attack itself is over. Recurrency can always be attributed to some cause such as anemia, cardiac weakness, or indigestion, and the attacks cease to take place when the cause has been removed.

Paroxysmal vasomotor attacks (Gower's vasovagal attacks) are also easily confused with petit mal. According to Zabriskie (305) "They are characterized by tachycardia, throbbings, flushing, dizziness, and parathesias, and may be accompanied by slight confusion and a vague fear of impending danger." They do not cause loss of consciousness, and are rarely if ever accompanied by twitching.

Although *hysteria* often proves to be a diagnostic stumblingblock, it almost invariably has certain characteristic earmarks which permit differentiation. Emotional excitement commonly precedes the appearance of symptoms. During attacks the loss of consciousness is not complete, the pupils are not

dilated, the eyes are not turned and are frequently closed, and there is no involuntary passage of urine or feces. Because of the tendency for hysterical patients to overventilate the lungs the excretion of carbon dioxid is sometimes so great that symptoms characteristic of tetany develop. These may be mistaken for epileptic convulsions by the unwary.

The symptoms of *aural vertigo,* a condition due to labyrinthine disease, are very similar to those of epilepsy.

Seizures due to syphilitic infection of the brain, arteriosclerosis, anemia, brain tumor, spasmophilia, and infection should not be classified as true epilepsy, but rather as symptoms of the fundamental condition.

A complete physical examination with the usual clinical and laboratory tests should suffice for differentiation between epileptic conditions and the attacks or syncope due to Stokes-Adams syndrome, paroxysmal tachycardia, polycythemia, various types of anemia, impairment of the cerebral circulation, cerebral arteriosclerosis, dementia præcox, migraine and chorea.

CHAPTER V

Prognosis

Several aspects of the prognosis of epilepsy must be considered. Each individual subject to epileptic seizures is exposed not only to the physiological effect of the attacks and of the conditions responsible for them, but also to many environmental factors which, although quite harmless during full consciousness, involve great potential danger during temporary obliviousness to surroundings. In addition to these immediate considerations, every epileptic must recognize the possibility that in some types of epilepsy at least there may be an hereditary factor and that marriage may perhaps be detrimental to the good of the race. The exact importance of these various aspects of epilepsy has not yet been determined, but it is probable that their relative value varies in each case.

Seldom does a seizure, *per se,* prove fatal, unless the patient has been exhausted by previous recurrence of seizures at short intervals. Just what effect each attack has in undermining the well-being of the subject is still unknown, but there seems to be fairly general agreement that harm of some sort does result, and that it is highly desirable to prevent establishment of the "epileptic habit." Because of

this, great efforts have been made to minimize the number of seizures by treatment. Herpin (116) states that prognosis cannot be considered favorable after a patient has suffered more than one hundred major attacks, while other writers believe that after five years' duration the prognosis of epilepsy is poor. That petit mal tends to develop into grand mal, and that when epilepsy begins in childhood the attacks tend to increase in frequency and severity are well-recognized observations. Some authors believe that the prognosis is particularly poor when epilepsy develops in children between 6 and 14 years of age. In my experience, this has not been the case when the régime of the patient is based upon good hygiene and ketogenic treatment is maintained. Muskens (216, p. 361) states that "Féré points out correctly that epilepsy, where the fits are limited to one side, has a more favorable course than ordinary epilepsy." For seizures resulting from definite cranial defects due to trauma the prognosis is good. On the whole, increase in the frequency and severity of seizures appears to be associated with mental deterioration and *vice versa*. In association with brain lesions, particularly during childhood, epilepsy seems markedly to affect the intellect. If, on the other hand, attacks are not too frequent and severe and there is no apparent pathological involvement of the central nervous system mental impairment is not a striking sequel. There may be deviation of the personality or intellect during seizures, and complete recovery in the intervals of normality. Many patients, however, suffer from epilepsy for years with-

out evident mental or physical injury. The belief that for adults with frequent attacks of grand mal the outlook is better than for individuals with petit mal probably depends upon the fact that the more severe condition usually receives more thorough and continuous treatment. Whether the poor prognosis generally to be expected in mentally impaired patients is due to inability to follow with sufficient care the régime necessary for successful treatment, or whether irreparable damage accounts for the lack of improvement in mentally deficient individuals has not been fully ascertained. About all that can be said concerning the permanence of improvement has been summed up by Shanahan (261) in the thirty-second Annual Report of the Craig Colony for Epileptics: "The longer the period of freedom from seizures and the better the adjustment to an ordinary environment, naturally the better the prognosis. Carelessness in the mode of life may result in a recurrence of seizures even in the most hopeful case."

Because data have not been uniformly collected it is very difficult to obtain definite information about the mortality of epileptics. As far as can be judged, however, children with organic lesions who are subject to frequent seizures tend to die before maturity, particularly if they are mentally degenerate. Without mental impairment the outlook is better, and the patient may often expect to live as long as a normal individual. Statistics quoted by Muskens (216, p. 359) show that the death rate of epileptics is highest between the ages of 25 and 30 years. At the Monson State Hospital in Massachusetts the average

age of death in 205 patients examined at autopsy was 38.9 years in individuals with apparently normal brains, and 41.1 years in individuals with abnormal brains (86). At the Craig Colony for Epileptics it was 30 years in 271 cases (86). The only conclusion which can be safely drawn from these figures, however, is that probably epilepsy somewhat reduces the length of life.

Little is known about the effect of individual development upon epilepsy, except that in certain instances periods of emotional or physical change are associated with an increase in the severity of the disorder. For example, in women the establishment of menstrual function, marriage, and the climacteric do not influence the prognosis favorably.

The environmental hazards to which an epileptic is exposed in private life and in industry vary greatly in character and severity, and should be carefully guarded against. Serious injury may be done to both the patient and those in contact with him unless the danger of certain occupations is recognized. If the epileptic drives a car, for instance, the occurrence of an attack in the heavy traffic of large cities or much used highways is liable to result in very undesirable consequences. If potentially injurious tools are employed in a trade, special precautions or supervision are necessary, to protect both the epileptic himself and those about him. Even when the patient does not attempt occupations which involve such specific danger, special care is necessary, for unless habitually there is ample warning an attack may take place on the street, near a hot stove

or fire, near sufficient water to cause drowning, near open windows high above the ground, or in other places where there is great possibility of injury. Suffocation by the pillows and coverings of the bed is a constant source of danger, and should be guarded against by the use of hard hair pillows. For epileptic children the duration of life in large measure depends upon the constant presence of an attendant who can provide adequate protection during attacks. For adults this precaution is, on the whole, less necessary because both additional warning and general experience permits more self-protection.

Another type of hazard must also be avoided, *i.e.*, great emotional and physical strain. Epileptics cannot stand the wear and tear of warfare, for instance. They should not be required to carry continuous burdensome responsibility, but in avoiding this there is no reason for complete withdrawal from life. In the Thirty-second Annual Report of the Craig Colony for Epileptics (261) emphasis is laid upon the fact that "epileptics of better mentality would be able to live fairly well as wage earners and could accomplish vastly more than the majority of people think possible, if the general public would appreciate their capabilities." In suitable occupations many epileptics can be almost as efficient as normal individuals and derive distinct benefit from their work. Since occupation greatly influences the prognosis of epilepsy, its effect on each patient should be carefully considered, and the necessary adjustments made to remove undesirable features. If at the same time public prejudice against the

employment of epileptics can be diminished, both the handicapped individual and the community will benefit.

Although, as yet, no treatment has been found which in all cases effects cure, therapy seems greatly to increase the chances of a favorable prognosis. The earlier it is established in the course of the disease, the greater is the hope for complete recovery, particularly if the patient is comparatively young. In certain individuals seizures may cease spontaneously for months or even years, only to return again if precautions are not taken. Complete relief of symptoms has been obtained by various methods of treatment, but there is not yet enough data to compare all methods in the same way. The prognosis is modified and sometimes changed by the use of bromides and luminal; it is changed by the use of special diets, more particularly the ketogenic diet which relieves symptoms in 30 per cent of the children treated by it. Reports are beginning to appear in the literature which ascribe equally good results both in children and in adults to dehydration (84, 196). Time will show how much the prognosis can be modified by these various methods of treatment; it can at least be said that with proper treatment epilepsy need no longer be considered a hopeless disease if it has not progressed to the point of damage to the brain and feeble-mindedness.

Concerning the desirability of marriage for epileptics there is still great difference of opinion. In most instances the emotional strain involved does not prove harmful to the patient, and the course

of the disorder in the individual is influenced but little.

The great problem to be considered is the racial significance. In certain families (*e.g.*, the Kallikak family) the condition seems definitely to be passed on from one generation to another, while in other families it appears to develop sporadically and only as a chance occurrence in the individual. Among physicians, belief in the non-hereditary type seems to be increasing, in spite of the fact that as yet there is no definite proof upon which to base conclusions. When no hereditary factor can be found and epilepsy appears to have developed as the result of special conditions within an individual, the question of marriage involves problems comparable in many ways to those raised by the occurrence of encephalitis lethargica or polioencephalitis. Data which demonstrate the direct effect of this type of epilepsy upon subsequent generations are lacking. There is no certainty that the taint will be transmitted to the offspring and there is probability that any individual child will be free from it. As observers come to appreciate the fact that seizures, *per se,* do not necessarily render an individual socially undesirable, in the consideration of marriage more importance is being given to the value of the epileptic and his family in the community. When epilepsy appears to be individual rather than hereditary and develops in a person who contributes generously to the well-being of the community, there can be comparatively little objection to marriage with a healthy mate who is not predisposed. Even were the disorder heredi-

tary under these conditions, the marriage would probably be valuable rather than harmful to the race, for not all the children would carry the epileptic taint, and the few abnormal offspring would not be a social burden. In fact the individual subject to seizures might himself come to assume heavy public responsibility or even develop into a great genius. According to Gowers (109), if parental epilepsy has been inherited it is improbable that all the offspring will be non-epileptic. This is a judgment to be weighed thoughtfully in the balance. If the traits accompanying epilepsy are those of degeneracy, as they consistently are in some families, marriage is highly undesirable; if, on the other hand, they are socially valuable, their propagation will more than compensate for the continuation of the epilepsy.

The development of epilepsy in the parent after birth of the children probably has no bearing on the future of the offspring and is a purely individual problem. There is no evidence that under these conditions predisposition to epileptic seizures has been transmitted to the next generation.

The condition known as pycno-epilepsy, often stops suddenly for no known reason and entirely without reference to any form of treatment.

CHAPTER VI

Symptoms

The manifestations of epilepsy vary so greatly in different individuals and even in the same individual at different times, that it is possible only to outline the general course of what might be called a typical seizure, and to point out certain temperamental characteristics, which are thought by some observers to be commonly associated with epilepsy.

Grand Mal (Major Fits).—Attacks of the more severe form of epilepsy, so-called grand mal, differ greatly in detail, but almost invariably pass through the same phases. Their frequency varies in different patients, but is apt to remain approximately uniform for long periods in any given individual. Often seizures begin only during sleep or in the morning just after waking. The intervals between attacks may be hours, days, weeks, or months in length.

Only between one-third and one-half of all patients have any warning of the onset of a seizure. The rest suddenly lose consciousness and, uttering a loud cry, fall to the ground in convulsions. The *aura* or warning assumes so many forms that no attempt will be made to delineate its characteristics. Suffice it to say that each patient comes to know that a certain unusual sensation, visual or auditory

hallucination, pain, or psychic condition is apt to be followed either immediately or after an interval by the convulsive attack. In some instances the seizure fails to follow this so-called aura, but usually the more severe symptoms develop in regular sequence. The length of time that elapses between aura and convulsion remains, in the long run, constant for each patient, just as do the other details of the syndrome.

In the first or *tonic stage* of the attack muscular contractions fix the limbs in irregular positions. The head may be pulled to either side and, like the trunk, is held stiffly. The features are distorted and the patient is very pale until rigidity of the muscles stops the movements of respiration. The pallor then gives way to suffusion and finally to lividity. Contraction of the masseter muscles frequently results in severe biting of the tongue. The eyes which may be either open or closed are insensitive. The pupils dilate as cyanosis increases. In most patients this tonic stage is very brief, lasting only half a minute or less.

The succeeding *clonic stage* begins when cyanosis is intense. All the muscles of the body become vibratory, and undergo fixed rhythmic contractions which usually begin in the legs and extend upward in irregular sequence. In the clonic spasm the limbs, head, face, and jaw are jerked violently, the eyes are rolled upward or to the side, the trunk is twisted, and the diaphragm contracts rhythmically. As the air is thus forcibly expelled from the lungs, the patient froths at the mouth, grunts, coughs, and makes stertorous noises. If the tongue or cheeks have been

bitten, the frothy saliva is tinged with blood. The bladder and sometimes the bowels are emptied by the muscular contractions. If the attack is very severe, the patient becomes livid and appears to be at the point of death. Hemorrhages occur in the conjunctivæ and other parts of the body, and it is said that in very rare cases the heart ruptures. The blood pressure rises at first and then suddenly falls and remains low. The pulse is rapid. As the intervals between spasms lengthen the remissions are more complete, inspiration is less restricted, and the cyanosis diminishes. The muscular contractions, however, continue to be strong up to the last jerk. This stage of an attack may continue for only a few seconds or may persist for between three and five minutes.

In the *stuporous stage* which follows, the subject relaxes completely and lies senseless and prostrate. This condition may persist for a few moments or for hours before the patient can be roused.

On wakening, epileptics have no recollection of what has occurred and occasionally do not even remember events which immediately preceded the onset of the attack. Some jump up ready to resume activities where they were left off, but more frequently these grand mal seizures leave in their wake a feeling of exhaustion, great fatigue, and a severe headache which may continue for several hours. When this is the case the patient is irritable and wants to be left alone. Individuals who do not suffer from this unpleasant aftermath are apt to have felt wretched for several days before the seizure and to

experience a sense of relief when it is over. In rare instances glycosuria follows the attack.

Petit Mal.—Minor attacks of epilepsy are often so difficult to distinguish from non-epileptic conditions that their true character is revealed only by their periodic recurrence. In some patients they consist merely of momentary loss of consciousness, so-called "absence," while in others they appear as fainting spells or periods of dizziness with peculiar motions. The patient rarely falls during these seizures, but the head may be dropped forward or turned to one side, the eyes may become fixed and expressionless, and the arms may be contracted. As time goes on petit mal tends to become more severe and to develop gradually into grand mal. The two conditions are frequently associated. Attacks of petit mal sometimes recur at very brief intervals. In one case under observation more than eighty took place in one day. This is not usual, however, and in the majority of subjects the number varies from two or three to a dozen a day.

Jacksonian Epilepsy.—Jacksonian epilepsy results from abnormalities of the cerebral cortex and is frequently due to brain tumor. In most cases convulsions are restricted to the region presided over by the abnormal part of the brain, but in some patients they become generalized before the end of the attack. If they are widespread from the beginning, this type of epilepsy is very difficult to recognize. The aura, when they occur, are apt to be motor in character. Holt and Howland (123, p. 559) have described Jacksonian epilepsy as localized spasms of different

groups of muscles in the face, arm, or leg with the retention of consciousness.

The epileptoid convulsions which occur in 33 to 50 per cent of children with cerebral palsy and hemiplegia usually begin on the paralyzed side. As they increase in frequency, however, they eventually become generalized.

The Intervals Between Attacks.—If the intervals between attacks are not very brief, patients usually feel quite well. It is not uncommon, however, for them to suffer from headache for a while before the seizure begins or to have a strong sense of anxiety and fear. At all times they are very susceptible to fatigue.

Status Epilepticus.—In the condition known as status epilepticus seizures recur at such brief intervals that there is no opportunity for complete recovery from one attack before the next begins. As many as 150 may occur within twenty-four hours. Because of the continued excessive muscular exercise involved in the convulsions and because the heat-regulating mechanism at the surface of the body is somewhat disturbed, the temperature may become very high. As might be expected, the pulse rate simultaneously rises, in some cases until it is very difficult to count. The body is bathed in a cold, clammy sweat. If the patient is not fatally exhausted by the almost continuous convulsions, the intervals between attacks gradually increase in length so that recuperation is possible. Status epilepticus frequently ends, however, with cardiac dilatation, pulmonary edema, loss of reflexes, and death.

Pycno-epilepsy.—"Pycno-epilepsy" and "myriad spells" are terms used to designate a condition which bears some resemblance to epilepsy. They refer to rapidly recurring attacks which "come on suddenly without warning and consist of complete inhibition of mental activity without appreciable loss of consciousness" (247). These develop at intervals of a few minutes and are of briefer duration than attacks of petit mal. The incidence is highest between the ages of 4 and 12 years. The children subject to these attacks are often unusually bright and active at school and manifest none of the typical epileptic characteristics. At no time do the spells become convulsive. There may at most be enuresis, loss of pupillary reactions, and slight turning of the head and eyes. Although some authors report that epilepsy has developed in individuals who were subject to pycno-epilepsy during childhood most observers agree that the occurrence of these "myriad spells" is of less serious import than epilepsy. Drugs do not seem to influence them, and no other type of treatment has been found effective. Sachs believes that the prognosis of pycno-epilepsy is better than that of epilepsy proper. After continuing for weeks or months it suddenly stops completely in most patients.

Epileptic Equivalents.—When abnormal mental conditions take the place of an epileptic seizure or develop after an attack of grand or petit mal, they are known as epileptic equivalents. These states in some patients are the first evidences of epilepsy and recur from time to time before the more character-

istic syndrome appears. They may consist merely in a change in disposition, or in fits of anger, or destructive violence. Usually the patient has no remembrance of them after they have passed.

Atypical Attacks.—Although almost no epileptic attack corresponds exactly to the general description already given, some differ so markedly from the standard as to be considered atypical. In many cases, especially during childhood, the aura is lacking. In other instances, the tonic stage is elaborated by turning, running, jumping, and other unusual activities. Some patients run amok. In petit mal the symptoms may be aborted, consciousness may not be lost, or the patient may carry out some complicated performance. In grand mal the occurrence of the aura without other manifestations should be considered an aborted attack.

Nocturnal Epilepsy.—"Nocturnal epilepsy" is a term which may be applied to any form of epilepsy in which seizures occur only at night or during sleep. The condition is probably far more common than many observers suppose, and may exist for years without being recognized. Sooner or later, however, the occurrence of an attack during the day or in the presence of some onlooker leads to its recognition.

Epileptic Characteristics.—Although individuals subject to epilepsy vary greatly in character and in intellectual ability, many observers feel that certain personal traits are almost invariably associated with the epileptic disturbance. The lack of social adaptability attributed to these individuals may perhaps

be a direct symptom of epilepsy, or it may result from constant dread of the onset of an attack in public or in unfavorable circumstances. Whatever its cause, it is undoubtedly a characteristic of many subjects of epilepsy, particularly of those whose mentality is low. It seems to be closely allied to the overbearing conceit and assurance of many of these patients which is out of all proportion to their accomplishment. Because some of the great figures of history have been subject to epilepsy, Lombroso has been led to believe that genius is epileptoid in its origin. Nisbet does not go so far as to draw this conclusion, but he says that "Occasionally there is a great intellectual activity produced by the epileptic condition, which seems to be caused by a wave of morbid excitement passing over the different cerebral centers." Careful survey of all the different types of epileptics will raise the question, however, of whether these inspirations may not be quite unrelated to the diseased condition, for in any large group of unselected epileptics there are always many whose mentality is far below normal. That moodiness and egocentricity are often associated with epilepsy has long been recognized and various authors have pointed out that individuals subject to convulsive attacks are ruthless in the pursuit of their own ends and quite inconsiderate of others. Moral atrophy is not uncommon, and general blurring of thought and judgment. Those who have had experience in the care of these patients realize only too clearly that they have a morbid optimism regarding their malady which leads them into dangerous

situations or into undertakings which they are entirely incapable of carrying out. Attempts to restrain their ambitions so that they may be more nearly comparable with possibility are apt to reveal delusions of unjust treatment.

CHAPTER VII

Prophylaxis

To outline the prophylaxis of epilepsy is very difficult, because of the fundamental character of the disorder. In no two patients are the causes of seizures identical, and therefore in no two instances can identical preventive measures be employed. There are, however, certain general principles upon which the life of susceptible or predisposed individuals can be based in order to minimize the effect of possible aggravating factors. In certain cases, need for the employment of prophylactic measures is obvious, in others there may be little indication that epilepsy is likely to develop until after a seizure has taken place.

The type of prevention necessary when there has been a long family history of mental deficiency and epilepsy consists in measures to prevent continuation of the family, as well as in measures to keep the individual free from possible attacks. Since there is little likelihood that the progeny will suddenly become free from the epileptic blemish, application of eugenic principles is essential for the well-being of the race. For the good of each member of an epileptic family, attention must be paid to all factors which favor and prevent the development of seizures, be-

cause, even with a poor background, the individual himself may remain of value to the community. This prophylaxis for the good of an existing individual is essentially similar to that desirable for the acquired type of epilepsy.

Reduction of mental, emotional, and physical strain to the minimum, as in the prevention of tuberculosis, seems to reduce the incidence of seizures to its lowest point. This is true whether the potential epilepsy be inherited or a purely individual disturbance. Punctilious abstinence from alcohol is, of course, necessary. Avoidance of all infections, particularly those which, like syphilis, weaken the nervous system, is essential. Special training and education adapted to the peculiarities of each subject appear to strengthen susceptible individuals and help in the establishment of a normal life.

Prevention of the seizures which follow hemorrhage at birth must depend upon the work of the obstetrician and perhaps upon special brain surgery. It has been discussed at some length by Crothers and other writers.

CHAPTER VIII

Treatment

Because the first apparent evidence of epilepsy is usually a seizure, physicians are seldom called to see epileptic patients until acute symptoms develop. Care during attacks is, of course, important, but the value of such therapy is almost entirely temporary. Only by removing the fundamental disorder can subsequent attacks be prevented. The physician should, therefore, know the various possible causes of attacks and be familiar with the theories upon which the present methods of treatment are founded. In this way he may be prepared to avoid any action which might harmfully influence the progress of a given case.

The measures to be employed during an ordinary attack are comparatively simple and easy to carry out. They should be known to all persons in frequent contact with epileptic individuals, and the few special articles required for treatment should be readily accessible at all times.

The other more important phase of treatment involves consideration of many complicated factors, each of which must be carefully weighed in the balance by the physician if therapy is to be adequately comprehensive. The need for special dietary,

medicinal, and surgical treatment, as well as for the maintenance of a régime providing suitable physical, social, and mental hygiene must be recognized; and great ingenuity must be employed in establishing for the patient a mode of life which will give the proper value to each factor concerned. The diagram in Figure II illustrates the interrelationship of the different aspects of treatment and gives an idea of the complicated problem which each case of epilepsy presents to the physician. If the fundamental cause of seizures can be entirely removed by surgery, the various other factors probably enter into treatment for a short time only and as secondary considerations. After the period of convalescence from operative procedures, they usually retain little more importance than in the life of normal individuals. When, however, surgical intervention is uncalled for, the success or failure of treatment depends entirely upon the nicety with which diet, medication, and physical, social, and mental hygiene are adjusted to the requirements of the patient.

Treatment of the Seizure.—The first procedure in the treatment of an epileptic attack is to protect the patient from potential danger. Consequently, children subject to epilepsy and adults whose attacks begin suddenly and without warning at all times require companionship. The risk of injury during the convulsive stage can be minimized by placing the subject upon a bed, but if this is impossible it is sufficient to remove the patient from the proximity of furniture and other hard objects against which he may strike. During the clonic stage, measures must

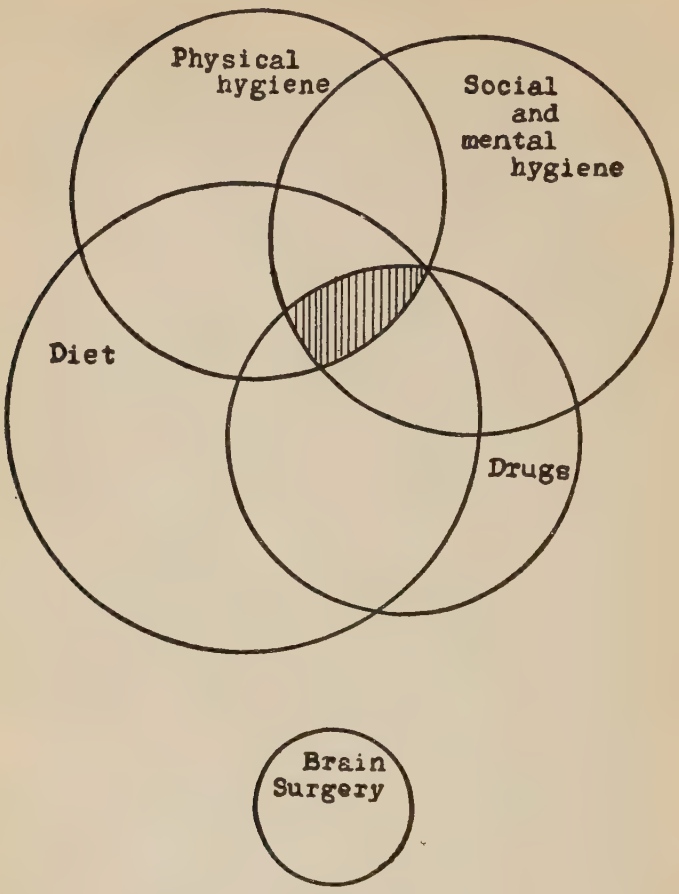

FIGURE II.

The Interrelationship of the Different Aspects of Treatment for Epilepsy.

be taken to prevent the head from striking the floor. Early in the attack clothes should be loosened around the neck, and a piece of cork, rubber, or soft wood placed between the teeth to prevent biting

the tongue. Forcible restraint is of no benefit. Since most seizures last for a few minutes only the use of hot baths and the administration of chloroform, morphia, and other drugs are unnecessary, unless there is peculiar need for conserving the strength of the patient. For individuals subject to serial attacks or in status epilepticus the physician can recommend special measures of this type, and adjust the doses of hypnotics to size and age.

The sleep which immediately follows an epileptic convulsion is beneficial and should in most cases remain undisturbed. If it is interrupted after too brief an interval, headache and marked discomfort are apt to ensue, whereas if it continues until the patient wakes spontaneously the after effects of the attack may be less severe.

The fact that when the epileptic seizure is preceded by a distant aura or warning it can sometimes be aborted has been recognized for many years, but no universally successful measures of abortion have been found. Usher Parson in 1851 (221) said: "In cases where the fit commences with a sensation of cold air, creeping along one of the limbs toward the head, apply a string around the limb, and direct the patient to draw it tight, when the sensation is first felt, by twisting a stick, which is to be worn in the string ready for the purpose." He reports that seizures have been averted in this manner for months. Many other procedures have been suggested to ward off attacks, but they need not be here discussed. That which has recently been found most effective is the

inhalation of amyl nitrate or mixtures of carbon dioxid (181).

Removal of the Cause.—The fact that thoroughly effective treatment depends on full understanding of the fundamental cause of a disorder makes it essential to remove all obscuring factors whenever the diagnostic problem is in the least complex. This is particularly necessary in the case of epilepsy, for in this disorder some of the causative factors have not yet been fully explained and the very character of the disturbance makes it particularly easy to veil the points at issue. The first step in treatment is, therefore, to correct in so far as possible all physical and functional abnormalities whether or not they appear to be in any way relevant to the problem under consideration. When this has been done, specific therapy may be instituted.

In the past, many attempts have been made to explain epilepsy as the result of intoxications, infections, functional disturbances, irritations, injuries, and other irregularities. As knowledge increases, however, it gradually becomes evident that no single one of these conditions is universally responsible for the production of epileptic seizures, but that any one of them may play some part in a given case of epilepsy. Consequently, if we are to attain broad understanding of the epileptic problem, it is essential not to disregard these factors, but to evaluate the importance of each correctly. If this can be done there will be hope of explaining in full certain aspects of epilepsy which are now obscure. The best method of demonstrating the clinical influence of these vari-

ous complicating conditions is to minimize the effect of each by treatment.

Of the *intoxications* associated with epilepsy, those due to alcohol (absinthe), lead, carbolic acid, and certain gases are the most common. Alcohol and lead are clinically more important than the others.

The exact effect of alcohol is not understood, but observers have come to believe that it predisposes to epilepsy not only the individual who takes it, but also his descendants for a few generations. It is therefore to be strictly avoided by both epileptic and pre-epileptic individuals. Even a small quantity may induce a seizure in patients chronically subject to attacks. Large amounts are very injurious and evoke severe symptoms.

The apparently close connection between lead poisoning and convulsive attacks does not seem surprising when the possible action of lead in the body is considered. Aub and his coworkers (14) have discussed the physiology of plumbism comprehensively and have outlined the principles upon which its prevention and treatment are based. Their work should be understood by all physicians who commonly deal with epilepsy, for it is particularly important that patients subject to seizures should be effectively protected from exposure to lead poisoning and from the deleterious action of lead that may have entered the body tissues.

Smoking seems usually to have so little influence upon the course of epilepsy that abstinence need not be required of all epileptic patients. Muskens (216, p. 279) states that in 15 out of 2000 cases it

was the cause of attacks, and that in 3 instances epileptic phenomena ceased after the patient refrained from smoking. It is probable, however, that these individuals were in some way peculiarly sensitive to the effects of the habit.

Infection may favor the development of seizures by lowering the general resistance of the body as well as by directly injuring the central nervous system. For this reason, as an incidental in the handling of epilepsy, specific treatment should be given all localized foci of infection, all general infections which seem unrelated to the epileptic condition, and all infections which selectively act upon nervous tissue. The measures to be employed for epileptic individuals differ in no way from those commonly used for normal individuals, except that care must be taken to avoid the establishment of conditions liable to induce convulsions. If such infections as encephalitis and cerebro-spinal meningitis do not receive suitable care during the acute stages hope of complete cure must be abandoned, for after-treatment of these conditions is ineffective. They may cause convulsive seizures immediately or not for months after their onset. The effect of a solitary tubercle of the brain is similar. Because the details of treatment for the various infections have been separately outlined in textbooks and special articles they will not be discussed here, for space must be reserved for consideration of the more obscure problems associated with epilepsy.

Increasing experience has shown that poor *body mechanics* plays a greater part in epilepsy than was

at first believed possible. It seems to be one of several factors which, when combined, result in seizures. Poor posture should, therefore, be corrected whenever found even if only slight. In several cases recently it has been found that attention to this and proper treatment of it, combined with dietetic treatment, resulted in greater improvement than dietetic treatment alone. Too much faith cannot be placed in the correction of posture, however, because this alone gives the desired results in only the very occasional case. I have one such case in my practice and Lennox and Cobb mention (180) two or three others.

Statistics show that *constipation* probably does not occur more often in epileptics than in normal individuals and that consequently it cannot be considered, *per se,* the cause of convulsive seizures. Since it is, nevertheless, a condition which affects the general health, some form of treatment is necessary. Careful adjustment of the diet or the administration of certain laxatives and cathartics usually provides sufficient control, but in some cases the best remedies are elimination of fatigue and improvement of general muscular tone and posture. Patients subject to constipation should avoid overeating and under-eating and need to take sufficient roughage and liquid daily. Fresh and cooked fruit often help to relieve the condition. If dietary measures prove inadequate, mineral oil, agar-agar, or bran may be given in quantities suited to the severity and type of constipation. Since these materials differ in their action, one is usually more desirable in a given instance than another. Mineral oil, which is inert

and bland, is effective because it oils the intestinal tract and is especially useful with a ketogenic diet. It is entirely unaffected by the processes of digestion and cannot be absorbed. If it leaks and soils the clothes, the dose is probably too large. Agar-agar, which is also bland, makes the feces soft by attracting and retaining water. It is very useful in preventing the formation of hard, ball-like stools. Bran, on the other hand, is an irritating residue which renders the stools bulky and moist by evoking increased intestinal secretion. Of the various cathartics, Carlsbad and Rochelle salts are the most satisfactory, especially when they are used with the ketogenic diet. The dose varies with the individual, but should always be large enough to produce at least one and preferably two free movements a day. Castor oil is comparatively undesirable on account of its irritating properties. It should be given only at intervals of between seven and ten days. The various other common mineral and vegetable laxatives all have their uses, but if the patient is restricted to the ketogenic diet, the vegetable preparations containing or coated with sugar must be avoided. In the author's experience the salts which act by drawing fluid into the large intestine and thus washing it out are the most satisfactory substances with which to combat constipation.

In the treatment of constipation which does not yield to simple or obviously specific therapy all conditions influencing the general well-being of the patient must be considered. The first step in this "constitutional" treatment is to relieve fatigue and

institute measures for improving the mechanics of the body. Fatigue, both physical and mental, is best handled by carefully adjusting the daily routine to the strength and needs of the patient according to the principles of good hygiene. Few unusual or peculiar procedures are necessary if the patient can follow with perfect regularity a program which provides adequate rest, exercise, and interest. Whether fatigue results primarily from poor posture, or whether poor posture is the chief cause of fatigue, has never been determined, but it is well recognized that cure of one condition seems automatically to relieve the other. Attention should, therefore, be given to both simultaneously if the best results are to be obtained. Comparable to the relation between posture and fatigue is that between physical and mental fatigue. Each acts upon and increases the other, and neither can be entirely remedied alone.

The effectiveness of osteopathic treatment in relieving constipation cannot be satisfactorily determined because of the paucity of available data. Not until results have been carefully studied in a large number of patients can it be ascertained. In the author's experience, which is very limited, osteopathic measures have, on the whole, been of no definite value. As soon as the combined effect of the various therapeutic measures is felt, constipation disappears, the general health of the patient improves markedly, and in most instances the number of epileptic seizures diminishes greatly. The improvement of the epileptic symptoms is sometimes so striking that it can hardly be attributed merely

to the cure of constipation. It must in some way be connected with general betterment of the patient's health.

In addition to constipation, ptosis and other gastrointestinal disturbances are closely related to fatigue and poor posture. No specific relationship has been proved to exist between these conditions and epilepsy, but since they lower the general resistance of the body they should always be remedied, in so far as possible, in the treatment of epilepsy. Specific medical treatment has met with some success according to Axtell (15). He believes that "intestinal surgery can give but little relief except where there is a definite history of inflammatory adhesions holding the angulations and flexures" and points out that thorough understanding of the patient's condition would often preclude the need for surgery. He thus favors limitation of the use of surgery to comparatively few cases, and throws doubt, as do many other authors, on its general effectiveness. Both Reed (245) and Armstrong (8) report that epilepsy has improved after colectomy, but they publish no report of the operative mortality and insufficient data convincingly to support their claims. Brewster's (41) report that in twelve cases of epilepsy colectomy brought no satisfactory relief supports such misgivings. Because the operation is serious and resultant benefit cannot be assured, there seems to be no justification for including surgical treatment of this sort in a course of epileptic therapy. The patient is far more likely to be helped by careful maintenance of a suitably arranged hy-

gienic régime, supplemented, if necessary, by specific medical care.

The administration of bacillus acidophilus and bacillus bulgaricus by mouth has been recommended for approximately the same reason as colectomy, *i.e.,* to do away with possible intoxication by substances present in the intestines. The theory is that a change in the intestinal flora will prevent the formation of toxic products or diminish their absorption. The author has been unable to find that this type of therapy influences the epileptic condition.

Concerning the desirability and effectiveness of surgical treatment for the various brain lesions that may be associated with epilepsy, there has been some difference of opinion. Did we know definitely the relation of tumors, scar tissue, cysts, and other localized abnormalities to the cause and symptoms of epilepsy the problem of treatment would be simpler. Ventriculographic studies fail to demonstrate the presence of incipient lesions and provide useful data only when marked cerebral displacement has resulted from the growth of tumors and cysts. They do not reveal the presence or position of scar tissue (50). Since, if surgery is to be employed at all, operation should take place before much damage has been done to the brain and before the disease becomes well established, ventriculography is of little diagnostic value at the onset when it is most needed. Several able surgeons (118, 4, 66) have from time to time grown very enthusiastic about the possibilities of cure offered by brain surgery, but after careful work on a large series of patients the usual

conclusion has been that for idiopathic or essential epilepsy brain operations are not to be recommended. Experience shows that although there may be great improvement for a few days or weeks after operation, epileptic attacks usually recur with such severity as to demonstrate the uselessness of the treatment. The fact that brain operations cannot be considered the cure *par excellence* of epilepsy, in no way relieves the physician from the responsibility of looking for cerebral hemorrhages, tumors, cysts, or cicatrization. In certain instances in which the tumor is so situated that its removal cannot permanently harm the patient, surgical treatment should completely relieve convulsive symptoms and lead to definite cure. If mental impairment accompanies epilepsy, the general prognosis is so poor that operation is hardly justified. Foerster and Penfield (91) have very recently found, however, that when the ventricles are displaced as the result of cicatrization following traumatic injury, the scar tissue can be surgically removed so that no more forms and fluid fills the space left vacant by the operation. In a large proportion of patients thus treated for traumatic epilepsy relief appears to have been permanent. In some instances individuals have been observed to be free from symptoms for as much as six years after the operation. It, therefore, looks as though surgery might prove very helpful in the treatment of traumatic epilepsy, although it is of comparatively little value in relieving the other types.

The effects of cervical sympathectomy are also

disappointing. Some authors report that this operation is followed by improvement, but in most instances they have watched the patient for so short a period after operation that it was impossible to have determined the ultimate effect of the surgery. Forster (94) suggests that cervical sympathectomy be employed only when the cervical sympathetic system functions abnormally.

If diagnostic methods improve so that changes in the nervous system can be discovered and localized at their onset, it is probable that surgical technique will keep pace and offer methods of procedure which will give greater hope of success. At the present writing, however, more promise is seen in the field of medical research.

The list of *miscellaneous disturbances* to which attention has from time to time been called in the treatment of epilepsy is extremely varied. Probably undue importance has been attributed to each, but there is little doubt that every item on the list is worth some consideration in epileptic therapy. With the proper background, any slight abnormality or irritation may suffice to evoke epileptic seizures, and consequently reduction of the number of possible disturbing factors is highly desirable. Care must be taken, however, to avoid attributing to these immediately provocative conditions the entire causation of epilepsy. To prevent eye strain with its consequent fatigue, even the slightest disturbances of vision require correction. The cure of worms, adherent prepuce or clitoris, and other irritations which may gradually affect the general health is beneficial,

but does not remove the cause of the epilepsy itself as has in the past been suggested.

Physical Hygiene.—In order to keep the patient as vigorous as possible, attention must be paid to the rules of hygiene in planning the daily program. This is not always easy, because, without unduly interfering with interesting occupations, provision must be made for exposure to the maximum possible amount of fresh air and sunlight, for regular periods of rest and exercise, and for the correction of faulty body mechanics. In the case of children or adults without definite occupations there is comparatively little difficulty in arranging the day, but when the activities of school or business fill a large proportion of the waking hours, inclusion of the necessary hygienic measures in the program often requires great ingenuity. Upon the physician rests the onus of deciding the exact balance to be maintained in each case between the requirements of physical hygiene and the demands of regular interesting occupations.

In a Northern climate, one of the greatest problems is to ascertain that the patient can spend the required amount of time out of doors in the sunshine during the winter, for the demands of any occupation tend to be most heavy during the few hours of sunlight. On the whole, patients seem to thrive better in the country where they can arrange schedules according to their own requirements. In the city it is not only more difficult to get out into the fresh air and sunlight, but it is almost impossible to follow interests of any sort without slipping into

the routine of people who pay but little attention to the need for getting out of doors. Experience demonstrates that throughout the early stages of treatment, before there has been any prolonged freedom from attacks, children make better progress if they spend a majority of the day, both winter and summer, out of doors in the country. Adults who require a great deal of opportunity to get out into the air and sun sometimes find that it is more satisfactory to spend the winter in a Southern climate where the daily program can be arranged with more freedom than in the North.

Provision for the requisite amount of agreeable *regular exercise* is also easier in the country and in warm climates. For children this problem seldom proves very difficult, but for certain adults it may severely tax the ingenuity of the physician, for not only must the degree of exercise be adjusted to strength and training, but its type must appeal to the taste of the individual. Exercise gives the maximum benefit only when it is pleasurable and taken at short intervals. If the regular occupation of the epileptic incidentally provides part of the daily requirement the problem is far simpler than when exercise must be distinct from the serious interests of the patient. In making arrangements for its inclusion in the daily program, the physician should bear in mind that when a patient has not been in the habit of exercising regularly, exertion must be slight at first and gradually increased. On the average, children, when in training, require the equivalent of a three or four mile walk daily, and adults the

equivalent of five or more miles. Only by careful observation, however, can the optimal degree of exercise be determined for a given individual. In so far as possible exercise should be taken in pleasant surroundings with congenial companions.

If it is impossible to find daily opportunity for exercise, the intervals of inactivity should be reduced to the minimal length. Some form of exercise is always essential for the maintenance of general muscular and bodily tone. Proper use of the body and the natural assumption of correct posture which accompanies good muscular tone prevent the development of undesirable strain. The fatigue which results from a suitable amount of physical exercise is healthy and beneficial; the fatigue which results from over-exertion, lack of vigor, and poor body mechanics is part of a vicious circle which includes many functional disorders and is extremely difficult to break. Because good hygiene requires even development of all parts of the body rather than disproportionate development of a few, the physician should always be on the lookout for particular weaknesses and devise special exercises to correct them. If this can be done, many disorders will be cured without specific treatment.

Constipation, for instance, may merely be a symptom of poor body mechanics which can be corrected by muscular training. If this type is cured, the improvement in the epileptic symptoms is often so marked as to be puzzling. Whether the change is due directly to cure of the constipation or to some factor which incidentally accompanies the establishment

of general well-being has not yet been discovered. The fact remains, however, that under these conditions there may be great reduction in the number and severity of epileptic seizures. In the author's experience, correction of poor body mechanics and constipation was followed in one case by cessation of epileptic attacks for seven years. In several other cases the results were less successful. Lennox and Brown (178) state that they "have seen complete cessation of seizures following orthopedic treatment for correction of the posture. One child in the eleven months before the beginning of treatment had had 175 major and thousands of minor seizures. A few weeks after the beginning of treatment, seizures ceased and have not reappeared in the five years which have elapsed since. In such cases it is not clear whether benefit is due to the relief of constipation, to improvement of intra-abdominal circulation, to increased ventilation of the lungs, or to decrease of fatigue as a result of improved musculature. Possibly all are concerned." For children, simple orthopedic therapy, regular inclusion of special exercises in the daily program, and the elimination of overfatigue usually suffice to remedy incorrect posture. For adults, more formal treatment may be necessary.

Since epileptic patients seem to be peculiarly susceptible to the ill effects of fatigue, care should be taken to provide opportunity for plenty of rest and sleep. Physical training, as has already been pointed out, eliminates one type of fatigue, but without relaxation it is hardly more than an added strain.

The amount of sleep required varies with the period of life and the individual. Young, growing children need far more than do healthy adults or aged people. Although no hard-and-fast rules can be laid down, a rough standard of requirements may be set. Table VI shows the amount of sleep which in general seems to be optimal at different ages. Some patients thrive when they take all the necessary sleep at once; others find this impossible and prefer to supplement

TABLE VI

THE HOURS OF SLEEP REQUIRED BY AVERAGE INDIVIDUALS AT DIFFERENT AGES

Age in Years	Hours of Sleep
Up to 6	14
6 to 8	13
8 to 12	12
12 to 14	11
14 to 17	10
17 to 20	9
After 20	9

a comparatively short night with rest during the day. Since sleep obtained before midnight is usually more refreshing than that which comes later, a comparatively early bedtime is to be advocated. The relative length of the periods of rest depends entirely upon the needs of the individual patient, but it is always desirable to allow ample opportunity for complete relaxation or sleep either before or after the noon meal. For children less than fourteen years old, it is the author's custom to insist upon an hour of quiet in the middle of the day. To facilitate the formation of regular habits and to prevent fortuitous curtailment of the time allotted for relaxation, a detailed outline of the day's activities may be writ-

ten down by the doctor. This permits clear definition not only of the hours of rising and going to bed, but also of the times for meals and for exercise. It thus relieves the patient of the burden of making constant decisions relative to general health. If he feels obliged to follow the program rigidly, he soon finds it easy enough to fit irregular activities into the time left free for just this purpose, and is not frequently tempted to upset the hygienic régime for the sake of passing interests.

Careful supervision of the diet, even when no specific dietary therapy is employed, greatly increases the well-being of the patient. Most epileptics tend to eat far too large a quantity of food or to strike an incorrect balance between the different types of food. Under-eating is not common except when the patient is under medical care. Of itself it does not influence the epileptic condition unfavorably, indeed fasting forms part of certain effective treatments, but if it continues too long or is unsupervised, the severity of symptoms may increase because the health has been injured and the resistance of the body lowered.

In some cases, general instruction suffices to remedy undesirable habits of eating, but it is usually necessary for the physician to prescribe in detail the exact diet suited to the patient. This is very difficult without the use of food scales, for the empirical standard of people who have habitually gone to dietary extremes constantly proves misleading. Until suitable habits have been formed, therefore, the caloric intake should be regulated with nicety. The

TABLE VII

THE HEIGHT AND WEIGHT OF NORMAL CHILDREN AT DIFFERENT AGES *

AGE, Years	HEIGHT		WEIGHT			
			Boys		Girls	
	Inches	*Centimeters*	*Pounds*	*Kilos*	*Pounds*	*Kilos*
	21	53.4	9½	4.3	9	4.1
	22	55.9	10½	4.8	10½	4.8
	23	58.5	12	5.4	12	5.4
	24	61.0	13½	6.1	13½	6.1
	25	63.5	15	6.8	15	6.8
	26	66.1	16½	7.5	16½	7.5
	27	68.6	18	8.2	17½	7.9
	28	71.1	19½	8.8	19	8.6
	29	73.7	20½	9.3	20	9.1
	30	76.2	22	10.0	21½	9.8
	31	78.8	23	10.4	22½	10.2
	32	81.3	24½	11.1	24	10.9
	33	83.9	26	11.8	25	11.3
	34	86.4	27	12.2	26½	12.0
	35	88.9	29½	13.4	29	13.2
	36	91.4	31	14.1	30	13.6
	37	94.0	32	14.5	31½	14.3
	38	96.5	34	15.0	33	15.0
	39	99.1	35	15.9	34	15.4
	40	101.6	36	16.3	36	16.3
	41	104.1	38	17.2	37	16.8
5	42	106.7	39	17.7	39	17.7
	43	109.3	41	18.6	41	18.6
6	44	111.8	44	20.0	42	19.1
	45	114.3	46	20.9	45	20.4
7	46	116.9	48	21.8	47	21.3
	47	119.4	50	22.7	50	22.7
8	48	121.9	53	24.0	52	23.6
	49	124.4	55	24.9	55	24.9
9	50	127.0	58	26.3	58	26.3

* From *The Internal Secretory System and Metabolism*, F. B. Talbot, Appleton & Co., New York and London, 1928.

TABLE VII—(*Continued*)

THE HEIGHT AND WEIGHT OF NORMAL CHILDREN AT DIFFERENT AGES

Age, Years	Height		Weight			
			Boys		Girls	
	Inches	*Centimeters*	*Pounds*	*Kilos*	*Pounds*	*Kilos*
	51	129.5	61	27.7	61	27.7
	52	132.1	64	29.1	64	29.1
10	53	134.6	67	30.4	68	30.8
	54	137.2	70	31.8	70	31.8
11	55	139.7	73	33.1	74	33.6
	56	142.2	77	34.9	78	35.4
	57	144.8	81	36.7	82	37.2
12	58	147.3	85	38.6	86	39.0
	59	149.9	89	40.4	91	41.3
13	60	152.4	93	42.2	97	44.0
	61	154.9	90	44.9	102	46.3
	62	157.5	103	46.7	109	49.4
14	63	160.0	108	49.0	112	50.8
	64	162.6	115	52.2	118	53.5
15	65	165.1	120	54.4	122	55.3
	66	167.6	128	58.1	126	57.2
	67	170.2	134	60.8	133	60.3
16	68	172.7	137	62.1	136	61.7
	69	175.3	144	65.3	139	63.0
17*	70	177.8	148	67.1	142	64.4
	71	180.3	152	68.9	144	65.3
18	72	182.9	158	71.7	...	...
	73	185.4	164	74.4	...	...
	74	188.0	170	77.1	...	...

* Very little growth after this in many girls.

exact number of calories needed depends, of course, on the height, weight, age, and activity of the individual. (See Tables VII, VIII, IX, X.) As an index of the suitability of a prescribed diet, the patient should be weighed at frequent intervals.

The theoretical rules to follow in balancing a

TABLE VIII

SYMOND'S TABLE OF HEIGHT AND WEIGHT FOR MEN AT DIFFERENT AGES *

Based on 74,162 Accepted Applicants for Life Insurance

Ages	15–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69
Weight	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5 ft. 0 in.	120	125	128	131	133	134	134	134	131	...
1 in.	122	126	129	131	134	136	136	136	134	...
2 in.	124	128	131	133	136	138	138	138	137	...
3 in.	127	131	134	136	139	141	141	141	140	140
4 in.	131	135	138	140	143	144	145	145	144	143
5 in.	134	138	141	143	146	147	149	149	148	147
6 in.	138	142	145	147	150	151	153	153	153	151
7 in.	142	147	150	152	155	156	158	158	158	156
8 in.	146	151	154	157	160	161	163	163	163	162
9 in.	150	155	159	162	165	166	167	168	168	168
10 in.	154	159	164	167	170	171	172	173	174	174
11 in.	159	164	169	173	175	177	177	178	180	180
6 ft. 0 in.	165	170	175	179	180	183	182	183	185	185
1 in.	170	177	181	185	186	189	188	189	189	189
2 in.	176	184	188	192	194	196	194	194	192	192
3 in.	181	190	195	200	203	204	201	198	...	...

* "The Influence of Overweight and Underweight on Vitality," *Medical Record*, 1908, lxxiv, 389-393. "In the higher ages it is probably better to be slightly under than over-weight."

TABLE IX

Symond's Table of Height and Weight for Women at Different Ages **

Based on 58,855 Accepted Applicants for Life Insurance

(*McClure's Magazine*)

Ages	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64
Weight	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4 ft. 11 in.	111	113	115	117	119	122	125	128	128	126
5 ft. 0 in.	113	114	117	119	122	125	128	130	131	129
1 in.	115	116	118	121	124	128	131	133	134	132
2 in.	117	118	120	123	127	132	134	137	137	136
3 in.	120	122	124	127	131	135	138	141	141	140
4 in.	123	125	127	130	134	138	142	145	145	144
5 in.	125	128	131	135	139	143	147	149	149	148
6 in.	128	132	135	137	143	146	151	153	153	152
7 in.	132	135	139	143	147	150	154	157	156	155
8 in.	136	140	143	147	151	155	158	161	161	160
9 in.	140	144	147	151	155	159	163	166	166	165
10 in.	144	147	151	155	159	163	167	170	170	169
11 in.	148 *	151 *	155 *	159 *	163 *	167 *	170 *	174 *	174 *	173 *
6 ft. 0 in.	151 *	155 *	159 *	163 *	167 *	170 *	174 *	174 *	178 *	177 *

** *Chemistry of Food and Nutrition*, by Henry C. Sherman, Ph.D., Sc.D.

* Figures projected by Dr. Fritz B. Talbot.

"In the higher ages it is probably better to be slightly under than over-weight."

TABLE X

ESTIMATED TOTAL CALORIC REQUIREMENTS FOR CHILDREN OF DIFFERENT AGES *

Age Years	Minimal Basal + 50 Per Cent		Maximum	
	Boys, Calories	Girls, Calories	Boys, Calories	Girls, Calories
1	900	900	900	900
2	975	960	1,200	1,200
3	1,050	1,040	1,300	1,300
4	1,100	1,050	1,400	1,400
5	1,200	1,125	1,500	1,500
6	1,275	1,200	1,700	1,600
7	1,350	1,275	2,000	1,800
8	1,425	1,325	2,500	2,000
9	1,500	1,375	2,600	2,300
10	1,575	1,425	2,800	2,400
11	1,650	1,500	3,000	2,600
12	1,725	1,560	3,250	2,900
13	1,800	1,610	3,500	3,200
14	1,975	1,650	3,750	3,400
15	2,050	1,680	4,000	3,600

* Taken from Talbot, F. B.: *The Internal Secretory System and Metabolism,* D. Appleton & Company, New York and London, 1928.

normal diet are: that the protein-content shall be about 1 gram per kilo of body weight; that the protein-intake shall provide approximately 15 per cent of the total number of calories; that fat shall supply about 30 per cent of the caloric quota, and carbohydrate about 55 per cent. These proportions must, of course, be altered more or less according to the needs of the individual, but they seem to be the mean about which most satisfactory diets vary. For adults this protein allowance is, probably, too large; for growing children, not quite adequate.

The type of food supplied to fulfill these theoret-

ical requirements need not be peculiar. It should in all cases be easily digestible and cooked without high seasoning. The more attractive it can be made to the patient the better. Since overloading of the alimentary tract is undesirable, bulky foods or those which contain a large proportion of residue are to be avoided, and no single meal should be very large.

Approximately even division of the caloric allowance into three parts is usually the most satisfactory arrangement, but if the patient habitually feels hungry between meals on this régime, it may in some cases be wise to divide the ration into four smaller parts. Before this is done, however, an attempt should be made to allay between-meal hunger by giving a cup of hot broth which contains no residue and has no food value. Never is it wise for patients to eat at irregular intervals or to supplement the calculated food allowance with tidbits.

The liquid content of the diet must be sufficient for the elimination of waste products. About 40 ounces of fluid are required daily by the average normal adult and more may often be taken to advantage. Of this quantity as much as 25 per cent may naturally be contained in the food. This may seem like a surprisingly large amount, but it must be remembered that many of the common articles of diet are composed largely of water. Milk, for example, contains about 85 per cent, and fruits and many vegetables even more. Entire reliance cannot, obviously, be placed upon food to supply the total amount of liquid needed. A certain quantity must be taken as such every day in one form or an-

other. If there is a tendency to cut down the fluid intake, it is sometimes wise for the patient to cultivate the habit of drinking two glasses of hot water immediately on rising in the morning. (The foregoing advice does not apply when rapid dehydration is desired.)

Dietary treatment of digestive disturbances is undesirable unless it can be accomplished with full adherence to the hygienic stipulations just set forth. Relief of constipation, for instance, by the administration of foods containing a large proportion of residue, is not to be generally recommended for epileptics. If, on the other hand, the constipation results from an insufficient fluid intake, dietary therapy may be entirely suitable. In any case, before the beginning of treatment for such a symptom, the instigating cause should be sought so that unnecessary therapeutic measures need not be employed. The choice of medication varies with the character of the disorder (see page 83) and the more general aspects of treatment depend on the abnormality which produces the symptom. Relief of ptosis or fatigue may in certain patients be a far more effective cure for constipation than any amount of medication. The importance of the establishment and maintenance of normal digestive function should at all times be emphasized.

Mental Hygiene.—The mental and emotional condition of an epileptic depends not only upon the reaction of the individual toward the occurrence of seizures, but also upon his attitude toward the people with whom he comes into frequent contact and

the atmosphere created by these companions. To ascertain the true state of affairs often requires great ingenuity on the part of the physician, because it is not uncommon for both the patient and his family to be totally unaware of factors responsible for emotional stress and worry. In some instances significant facts may be learned by direct observation or questioning of the patient and his family; in other cases the necessary data can be obtained only from friends or relatives who are able to look at the problem with perspective. Occasionally a trained investigator must live in the household for days or weeks before explanation can be discovered for existing attitudes and stresses. The importance of a thorough understanding of the emotional life of the patient deserves great emphasis, for an entirely satisfactory course of treatment cannot be devised without recognition of all sources of nervous fatigue. Slight changes in environment, occupation, and human contacts may be far more effective treatment for certain epileptic conditions than the most elaborate impersonal measures. This was found to be the case in one young lady who failed to respond to any type of treatment while at home, and who became free from attacks and has remained so for 18 months while living in Europe. A wise physician who understands the family as a whole, and also the personalities of its individual members, frequently has sufficient general experience and intuitive judgment to make the necessary suggestions without special training. Success is impossible, however, unless the sympathy, loyalty, and respect of the patient have been won,

for at best the same problem will recur many times, and the patience of all concerned will be sorely tried. The solution of psychological problems requires keen judgment, firmness, persistency, and courage.

As soon as the physician has determined the physical and nervous status of an epileptic patient, he should take steps to relieve whatever strains exist. Usually, treatment must begin with a period of complete relaxation. Physical rest can in most instances be obtained at home. Mental rest is far easier to procure in an environment where every little detail is not packed with suggestions of responsibility and the results of personal contacts. It is therefore usually wise for the patient to go away in order to get free from the atmosphere with which he is habitually surrounded. A change of scene has twofold value: it helps the patient to relax and fit into a normal round of life; and it also changes the mental attitude of the family which is often rendered uncomfortable by fear that a seizure may occur at any moment. If practical reasons prevent temporary separation of an epileptic and his family, readjustments may be possible, but they will of necessity be slower and more difficult because they must be consciously made by a group of people. There is less resistance against a change of habit which is ostensibly adaptation to new conditions, than against a change which must be made in cold blood. Stimulation of active interest in some engrossing but not worrying hobby may provide sufficient change to permit destruction of the insidious atmosphere of watchfulness and fear which sur-

rounds many epileptics and comes inevitably to wear upon their nerves. Even with such an occupation to shift attention, however, unceasing tact and good judgment must be employed to develop and maintain normal spontaneity and calm. Without strong character on all sides, adequate mental rest can hardly be obtained unless there is separation.

In the majority of cases, mere relief from worry, fear, emotional shocks, and the harmful features of social contacts is to be considered, *per se,* a temporary measure. For a while the restfulness of an existence which demands nothing benefits a nervously exhausted individual, but as soon as the novelty of calm has worn away, such an empty life will bring boredom. To ward off the nervous fears and worries that always accompany this frame of mind, the patient must be trained in so far as possible to lead a normal active life. This means not that ordinary problems are to be solved by others, but that the patient should be prepared to deal with them himself. Since he must understand how to meet the exigencies to which every one is subject and in addition how to handle suitably the added difficulties imposed by the epileptic condition, more training is necessary than for the healthy individual. This is frequently not appreciated by the parents and associates of epileptics. They usually assume that since the handicap is so great and so much normal pleasure is prevented everything must be done to increase the enjoyment of the moment. In their distress they are blind to the fact that satisfying pleasure does not originate entirely in selfish

lack of control. Even after definite explanation it is sometimes difficult to make them understand that complete lack of discipline decreases the ability of the patient to accept the hardships of his disease with philosophy, and thus reacts unfavorably upon the course of epilepsy. If every obstacle arouses resentment rather than the desire to act effectively, there will inevitably develop a sense of horror toward all difficulties which cannot be removed, and particularly toward the seizures. This, in turn, will grow into the relentless, wearing worry that is always harmful. In failing to provide training, people caring for epileptic patients also seem to forget the future. They hope, of course, that eventually the patient will be cured, but they fail to visualize clearly his position in the world after the seizures have ceased. This is readily to be understood, because epilepsy is distressing both to the patient and to those in contact with him; but it is in no way to be condoned. The physician must assume the duty of emphasizing that any one who is incapable of facing and dealing with reality labors under a serious handicap.

At the beginning of training the patient must not be overwhelmed by a flood of difficult problems. He should be carefully guarded from the need of making momentous decisions, and nothing should be allowed to overtax his strength. Not until there has been opportunity for a period of relaxation, should an epileptic be required to develop his nervous resistance by what might be called nervous exercise. During the period of rest, however, ample opportun-

ity should be provided for the pursuit of attractive hobbies. Emotional tension will thus be relieved by doing away with boredom, and the stimulation of spontaneous interest in some occupation will lead to the making of decisions without worry. As the patient gains self-confidence and strength his responsibilities and human contacts can gradually be allowed to increase, but never so fast as to upset his peace of mind. For children, the establishment of the right régime is easier than for adults, because fewer complexities are involved. They can be better protected from the nervous pressure caused by external conditions, for they have in general little sense of responsibility for their environment.

The country or seashore is usually the best environment in which to fulfill the requirements of mental and incidentally physical hygiene.

As soon as sufficient strength has been built up to withstand the wear and tear of ordinary, regullated life an epileptic child is better off at school than at home, provided always that his attacks are not so frequent or unpleasant as to make him an object of suspicion or ridicule to his companions. At the beginning of treatment, separation of an epileptic child from his brothers and sisters, except during short intervals, is desirable, for it obviates the strain of competition, particularly if the other children are of approximately equal age. Careful watch should be kept of the effect of brief social contacts, for it is greatly to the patient's advantage to mingle with the group as soon as the strain of

human contacts and the excitement consequent to them are within the limits of endurance. Isolation is undesirable except in so far as it provides the relaxation essential to mental and physical hygiene. The necessary adjustment to the group teaches many lessons that facilitate entrance into active life in later years. If the mentality of the patient is below normal, ordinary school is out of the question, of course, and special instruction must be given to develop latent possibilities and provide an interest which will keep the attention centered on the constructive side of life. For all patients suitable education has the advantage of providing definite means of controlling and training the temperamental difficulties to which the epileptic seems to be particularly subject.

Whether personal characteristics bear an etiological or consequential relationship to the epileptic condition has not yet been conclusively demonstrated. About all that is known concerning this subject is that the temperaments of most epileptic individuals of subnormal, normal, or unusually high intelligence tend to be similar in several respects. Strecker (270) mentions the following list of general characteristics: egotism, conceit, emotional instability, hypochondriasis, sickly sentimentality in religion, inadaptibility to environment, cruelty, laziness, irascibility, impulsiveness, excessive sexual and criminal tendencies, violent impulses: he refers to L. P. Clark and points out that he outlines the peculiarities less explicitly, but indicates that epileptics are subject to mood defect, egocentricity,

abnormal sensitiveness, and inability to meet the usual life situations.

Much has been written and preached about the value of psychoanalysis in the solution of mental difficulties, but its effectiveness in overcoming the emotional accompaniments of epilepsy has not yet been definitely proved. For some patients it seems to be helpful when employed directly as a therapeutic measure, while for others it appears to be valueless. In our present state of knowledge, it is hardly wise to rely upon it generally as a means of treating epilepsy. For children, direct, formal analysis is not to be recommended in any case. Young patients may respond very advantageously to environmental changes based on psychoanalytical principles, but it is undesirable for children to be conscious of the reasons for such changes except in rare cases. Just as psychoanalytical knowledge permits greater insight into certain educational problems, it may reveal to the physician reasons for conditions of strain which would otherwise be unrecognized. By adjusting the life of the patient so as to remove the causes of stress thus brought to light, it may be possible to employ what might be called a psychoanalytical type of therapy without in any way entering upon a formal analysis or suggesting to the patient that analytical knowledge forms a basis of treatment. As has already been pointed out, great benefit results from relief of every physical and mental strain, and it is desirable to employ all measures which can give such relief without harm. L. P. Clark (48) believes "that child-

hood is a fruitful period of new and unbearable stresses, and, in consequence, epileptic attacks often occur in one predisposed." "The next stressful period is at puberty." Much has been learned from psychoanalysis about the nervous difficulties of these two periods of development, and it hardly seems justifiable, since the need for relief of strain has been recognized, to fail to apply this knowledge in readjusting the life of an individual admitted to be under peculiarly severe stress.

Hypnosis is of a very different character. Some authors recommend its use in the treatment of epilepsy, but on the whole its value is questionable, particularly for children.

CHAPTER IX

Education

To outline an educational program suited to the needs of all epileptics is nearly impossible, for in each case the problem is unique. There are, however, certain fundamental principles to follow in attempting to develop the latent powers of each patient. Over-fatigue, both physical and nervous, must always be avoided, and occupations which may involve danger at the time of seizures to either the patient or his companions are to be omitted from the course of training. Needless to say, just as with normal pupils, every effort should be made to arouse spontaneous interest and develop potentialities to the fullest extent. Because the prognosis of epilepsy can rarely be foretold with certainty, the field of instruction is necessarily somewhat restricted. There is no use in providing training which cannot be utilized independently in later life, unless it be of immediate therapeutic value.

The details of education depend, of course, on the age, mentality, and social status of each patient. In so far as possible epileptic children should receive instruction comparable to that of normal children, and epileptic adults, training which will permit them to take their natural position in society.

Wallin (294) says that in general "the average epileptic in spite of the dementing tendency of the disease makes intellectual progress from childhood to adulthood. Consequently, institutions for epileptics should be made genuine training schools and not mere asylums." The mental capacity of patients seen in private practice varies greatly, but on the whole is normal or well above normal. This is not the case in institutions, for individuals who enter epileptic colonies are usually unfit, for one reason or another, to take their place in the world. Wallin (294) reports, for example, that in the New Jersey State Village for Epileptics at Skillman only 5.4 per cent of the inmates had a mental age of more than 13 years. Approximately similar conditions are to be found in other institutions. For patients of average or particularly high intelligence the educational problem consists essentially in establishing an adjustment between intellectual pursuits and the rules of hygiene, so that the individual will be able to employ the maximum proportion of his strength for constructive purposes. Intellectual development will proceed without difficulty if this can be done. For patients of less ability more ingenuity must be used in the stimulation of mental activity, in order to prevent stagnation and consequent intellectual degeneration. In considering the exact character of the instruction to be given patients without striking ability and independent means, many factors must be weighed in the balance. The expected mental and physical prognosis determines the type of occupation for which preparation is desirable, and

the sympathy and understanding of available teachers conditions the rate of progress.

In the early stages of epileptic therapy, it is often necessary, for a while, to place greater emphasis upon physical and mental hygiene than upon educational progress *per se*. Not until the patient has recovered from past fatigue and can make a fresh start is it wise for him to be subject to intellectual demands. During the preliminary resting period isolated training may be employed as a hygienic measure, but protection from the excitement and burden of competition with other children must be provided until a reasonable amount of strength has been acquired. Class work is far more tiring than isolated work. As soon as it seems wise to subject the patient to the strain of companionship formal education may begin gradually. At first, school hours should be reduced to a minimum so that the strength will not be overtaxed.

The children who enter large classes in a public school require special care. The physician can arrange for this more satisfactorily than can the parents, because he is able to outline impersonally and with greater insight the problems to be faced. If the head of the school understands fully the abilities and handicaps of an epileptic pupil, he can forestall many embarrassments by his coöperation and tact. The daily program can be so adjusted as to allow ample opportunity for rest, the length of the noon recess can be increased so that lunch may be eaten at home if the child is undergoing dietary therapy, and individual instruction may be provided to

stimulate interest or to compensate for previous educational deficiencies. Careful watch must be kept to determine whether the epileptic child is capable of competing with the rest of the class, for if he is not his work will soon become a source of worry and strain. It is far better to risk unnecessarily slow development of his mental powers than to overtax him nervously and physically by setting unduly high standards.

For well-to-do epileptics, more satisfactory education can be provided, because instruction by special tutors or in small classes makes it possible to regulate the severity and type of work with nicety. The irritations incidental to group work can be minimized, and rest and recreation can be so included in the daily program that fatigue need never develop. Such comparatively isolated schooling allows much more rapid intellectual progress than does instruction in large groups. Because it entails no obligation to maintain burdensome social contacts, it permits the epileptic to enjoy companionship with a minimal amount of strain. As strength increases, the number of social contacts can be gradually multiplied until the patient has become inured to the wear and tear of normal social life.

The degree of intellectual training to be given depends on the mentality of the individual. Some epileptics, for the most part those in institutions, are capable of learning only a simple routine trade, while others seen in private practice can outstrip university students in intellectual attainment. For all types, however, training is advantageous. Men-

tally deficient epileptics can be supervised most satisfactorily in an institution where they need not enter the competition of normal life. Thus protected, they may become socially useful and make commendatory advances. For patients who aspire to a university education a word of caution is necessary. In the large city universities each individual is lost in the crowd and the burden of excitement and nervous strain is comparatively heavy. In small colleges in the country, the general spirit tends to be more friendly and personal, and the generosity and thoughtfulness of classmates may minimize the epileptic handicap. Warning should be given, however, that occasionally a cruel student may be met with in any college group who will deliberately try to destroy the patient's peace of mind. In so far as possible the education of an epileptic should be preparation for a life of constructive activity. In the Thirty-second Annual Report of the Craig Colony emphasis is laid upon the fact that with suitable training "epileptics of better mentality would be able to live fairly well as wage earners and could accomplish vastly more than the majority of people think possible."

The vocation of an epileptic must be chosen with care. In general those which are suitable do not involve heavy mental and physical strain, and are not potentially dangerous to either the patient or his associates. The character and tastes of the individual determine in some measure the degree of strain involved. Work which is peculiarly tiring for one person may be quite refreshing for another. Certain

types of work, however, are never to be recommended. Employment in large, noisy factories imposes undesirable strain, and positions in which momentary irresponsibility may endanger life involve unnecessary risk. Epileptics should, for instance, avoid employment as elevator men, engineers on trains, railroad tower men or train dispatchers, chauffeurs, traffic policemen, harbor pilots, ship engineers, or other officials controlling the safety of groups or individuals. For such work they may substitute occupations on farms, clerical duties, library work, and the various activities associated with the fine arts, music, painting, and writing. Shopkeeping and manual outdoor labor are sometimes not only congenial but positively beneficial occupations. One of the chief requirements imposed by the epileptic condition, is the need for arranging the daily program so as to minimize nervous strain and responsibility. No vocation which prevents this is suitable for a person subject to epileptic seizures. Throughout education, emphasis should be laid upon this point and special instruction given which will enable the patient to reconcile this need with the demands of his regular occupation.

CHAPTER X

Recreation

Almost as important as the occupation of an epileptic is his recreation, for this relieves the nervous strain produced by continued application to any task. The choice of recreation depends, of course, on the tastes of the individual as well as on various other factors, for to be "recreative" an activity must be pleasurable. Patients whose attacks come only at night or after well-recognized warning have greater freedom of choice than those subject to attacks during the day or without warning. For all epileptics there are, however, certain restrictions, because it is fair neither to the patient nor to the public to participate in activities which involve serious potential danger. Except under special conditions, therefore, the driving of automobiles, bicycle riding, horseback riding, canoeing, swimming, sailing, and the use of firearms are to be avoided. For the good of the patient it is also desirable to eliminate from the list of amusements all activities which involve physical shock, great excitement, and severe, acute fatigue. This means that football, basketball, lacrosse, and hockey are not to be considered beneficial forms of recreation. Participation in games which permit adjustment of physical and

nervous fatigue to the strength of the patient is, on the other hand, to be encouraged. Golf and tennis, for example, excellently fulfill the recreational needs of many epileptics. Intellectual recreation which demands a certain degree of physical exercise is highly to be recommended. Gardening, outdoor photography which leads the patient to take long walks in the country, geology, and the study of birds and plants not only provide intellectual interest but also encourage desirable physical activity. To widen the sphere of interest and provide attractive emotional outlets other types of hobbies should be cultivated. Great refreshment can be obtained from enthusiastic study of some aspect of art, literature, music, or science. In providing for recreation the physician must always bear in mind the need for a suitable balance between physical and nervous activity and should ascertain that the hobbies and recreations of a patient offset the effects of his regular occupation.

CHAPTER XI

Medication

In epileptic therapy, drugs are usually employed to reduce the number and severity of seizures rather than to remove the basic cause of symptoms. Consequently, those most commonly given are sedatives. In addition to minimizing the injury produced by seizures, these drugs release both the patient and his family from the dread of very frequent attacks and thereby relieve an atmosphere of strain which tends to react unfavorably upon the course of the disease. Grand mal seems to be more amenable to medication than petit mal.

For many years the bromides were the first choice of physicians, but these have recently been superseded by luminal (phenyl-ethyl-barbituric acid) which according to Lennox and Cobb (180, p. 253) has become the "standard drug for controlling seizures." This, on the whole, appears to be the safest and most effective agent for long-continued use. Of the other substances which have been administered in the treatment of epilepsy comparatively few need be mentioned. Sodium and potassium borotartrate, zinc oxide, lactate of zinc, asafetida, nitroglycerin, ammonium chloride, and, in chronic inveterate cases, iodide of mercury have been used with-

out startling success. In a few instances, when the blood calcium content is low, the administration of calcium chloride has resulted in the disappearance of symptoms.

Although Sir Charles Laycock (52) recognized the therapeutic value of the bromides in epilepsy in 1857, it was not until several years later that the bromides came into general use. Radcliffe and Hughlings Jackson in 1864 came to employ them regularly at the National Hospital for Epileptics and Paralytics as therapeutic agents, and thereafter their use spread rapidly. After long experience in the use of bromides, there seems to be fairly general recognition of their effectiveness. Turner (290) in 1907 states that he has been successful in stopping seizures in 23.5 per cent of patients under bromide therapy. Binswanger (216, p. 342) gives approximately the same figures, and Cushny (63) says that "In an epileptic colony the number of fits per patient without bromide were 13.3 per month and while under treatment with moderate doses of bromide the rate fell to 1.5 per month. Very often there is no change until the tissues become saturated with bromide, but in other cases the fits disappear immediately after the beginning of treatment."

Concerning the optimal dosage there is still difference of opinion. Some authors recommend treatment with many doses of comparatively small amounts, while others feel that it is better to give the drug less often in larger quantities. Careful watch must, of course, be kept in every case for symptoms of intoxication, because tolerance to bro-

mides varies in different individuals. Experience seems to show that the majority of adults can take between 3-4 grams (45-60 grains) a day without harm for a period of several weeks. Larger doses produce only temporary improvement, and continued administration of smaller doses (2½-3 grams) for very long periods (*e.g.*, a year or more) may do serious harm. If for any reason large quantities of bromide are to be given, the dosage should be determined by Ulrich's method. Wuth (304) reports "that it is not wise to exceed a limit 'of concentration' of 125 mg. of sodium bromide per hundred cubic centimeters of serum for the average patient," and points out that "when the blood bromides increase beyond 150 mg. per hundred cubic centimeters of serum, - - - the patient is liable to intoxication symptoms." He feels "that if convulsions, in the more severe cases, cannot be controlled by bromides up to from 170 to 200 mg. per hundred cubic centimeters of serum, there is no use to attempt to push bromide therapy." Most authors favor long-continued use of the bromides, but in some instances there seems to be a point beyond which bromide medication is undesirable. Paterson in 1897 cited eleven cases in which improvement, sometimes quite striking improvement, followed cessation of medication after a long course of treatment. In each case the dosage must be nicely adjusted to the needs of the patient. For children, of course, it should be proportionately smaller than for adults.

Since in theory bromide and chlorid ions are interchangeable, therapy should prove more effective

when in the absence of chlorides a larger proportion of bromide can enter the tissues. To obtain the greatest benefit from bromide medication various physicians have, consequently, recommended complete omission of salt from the diet. As this makes food so unpalatable that the appetite soon lags, it is usually wiser in practice merely to require avoidance of all highly salted articles of food if therapy is to continue for long periods. Ulrich (216, p. 344) sometimes gives sedobrol to flavor food, instead of ordinary salt. Omission of salt from the diet is, *per se*, of no therapeutic value.[1] Only as an adjunct to bromide therapy is it to be recommended. It may either increase the effectiveness of a given dose of bromide, or make it possible to administer smaller quantities of the drug (287).

The bromides most commonly employed are the triple salts. Calcium bromide is, however, used by some physicians to compensate for a supposed deficiency of calcium in certain patients.

During a course of treatment with bromide salts, careful watch must be kept for signs of intoxication, particularly when the patient is at all delicate. The earliest manifestation of intolerance is the appearance of acne on the forehead and back. This is soon followed by foulness of the breath, intestinal disturbances, loss of appetite, symptoms of ataxia, and somnolence. Chronic bromism, which results from continual ingestion of large doses, may injure the heart and kidneys. It is to be treated by diuresis.

[1] This statement will be qualified in the discussion of the part played by salt in causing the retention of fluid in the body. See section on dehydration.

Administration of common salt also tends to cure it by facilitating excretion of bromide.

Luminal (phenyl-ethyl-barbituric acid), which has largely supplanted bromide in the treatment of epilepsy, is closely related to veronal and dial. Its chief advantages over the bromides are that for most patients it is more effective in stopping attacks, has fewer unpleasant after effects, and does not dull the mentality to such a marked degree. On the whole, it seems to be a more efficient medication for *grand mal* than for *petit mal,* but it is employed to combat both types of seizures.

Although it can apparently be taken with impunity by the majority of patients, it should be administered only under the close supervision of a physician because various risks are involved in its use. A few individuals appear to react specifically to the drug. For instance, in the author's experience, administration of 1½ grains to a girl 8 years old immediately produced wildness which lasted for a day and a half. This subject could not tolerate even the smallest doses. Occasionally luminal has the opposite effect when given in large doses, and produces sleep which lasts for two days or more. An irregular, macular, skin eruption sometimes develops when the drug has been used for a long time. This soon disappears if the dose is reduced or medication temporarily stopped. The chief danger involved in the administration of luminal is associated with sudden withdrawal of the drug after a course of medication. Unless the doses are gradually reduced, severe convulsions may ensue or even status epilepticus and

death. Experience seems to have proved that luminal is not a habit-forming drug because its use does not develop a craving such as is experienced after the use of opium and similar drugs. It has no influence on the sympathetic and parasympathetic nerves (9), but according to Pickworth the prolonged use of barbituric hypnotics may cause serious alterations in the white matter of the spinal cord.

The usual dose of luminal is 1½ grains (0.097 gram) daily. In certain cases, however, as much as 5-6 grains (0.324-0.389 gram) are given. The maximum daily dose for an adult is 10 grains (0.648 gram). Since luminal appears to irritate the brain substance, direct administration is not to be advised even when it is possible. The drug is usually given by mouth, but in status epilepticus may be injected intravenously in 2 per cent solution.

The value of sodium and potassium borotartrate in epileptic therapy has not yet been satisfactorily demonstrated. Marie, Crouzon, and Bouttier (203) in 1920 advocated the use of potassium borotartrate because of its beneficial effects, and Bigwood (34) also obtained good results from its administration. These he attributed to the fact that the drug was thought to cause acidosis. Talbot, Metcalf, and Moriarty (279), on the other hand, were unable to demonstrate any change in the acid-base equilibrium in the body after medication with these borotartrates. Their results agree in general with those of Lennox and Wright (168) and lead to the conclusion that the borotartrates control epileptic seizures less effectively than does luminal.

SECTION II

CHAPTER XII

Factors Necessary for an Understanding of Dietary Treatment

Introduction.—Before considering the dietetic treatment of epilepsy it is necessary to discuss some of the factors upon which such therapy is based. Various types of knowledge are valuable and even essential for a full understanding of any dietary treatment and other factors must be known whenever dietary therapy is given to children in whom growth produces special requirements. Since a child cannot be considered healthy if growth does not progress normally, the general problem of normal growth will be briefly discussed.

Growth.—It is difficult to define what normal growth is, but there are many tables which show the growth of the average child. Most of these average tables have been compiled from data obtained in the public schools, where a majority of the pupils come from an environment which is far from ideal for development. Consequently there is a discrepancy between such standards and the data obtained from children who live under more favorable conditions. In utilizing these average figures as a norm it is, therefore, necessary constantly to bear in mind that they do not represent the ideal which would be found

when all developmental conditions were favorable.

There are three periods of life in which the growth impulse is accelerated: *i.e.*, during the first six months of infancy; between the ages of five and seven years; and finally at puberty. A *seasonal variation* in growth has also been observed. Height and weight increase about equally from December to early April. From April to September there is a maximal gain in height without much gain in weight, while from September to December the greatest gain in weight occurs. So many factors influence growth, however, that there are many exceptions to these conditions.

Various features have been suggested as indices of nutrition by Dreyer (74, 75), Pirquet (236), and others (31), but it has become customary to base judgments upon the relation of weight to height. Since this ratio is easy to obtain and is a sufficiently accurate index of the developmental and nutritional condition, it is used as a standard for comparison throughout this book. In comparing with any such standard the figures obtained in a given case, it must always be remembered that individual conditions are rarely identical with average conditions and that within limits variations from the standard cannot be considered abnormalities. It must also be kept in mind that an individual whose height and weight correspond exactly with those given as the normal standard may upon clinical examination be found to be distinctly abnormal. I have found this to occur in both Mongolian idiots and so-called normal chil-

dren. When age is introduced as a third condition in the formation of a standard of growth, many more abnormalities will be revealed than when only weight and height are considered. This is well illustrated by the conditions found in dwarfism and overgrowth. It is desirable, therefore, to consider the age of any patient in estimating his physical status. Height-weight standards cannot be used intelligently unless the conditions of measurement are understood. In determining averages children less than five years old are usually weighed naked; while those five or more years of age are generally dressed. This must always be taken into consideration in determining the status of a patient. It must also be remembered that the weight of the clothes varies with the season. Because the figures for the standards have been obtained from children at school it has been impossible to obtain the weights before breakfast. This means that the standard tables give figures which are a pound or two larger than should be expected in the morning before food has been taken. Table VII shows the height and weight of normal children at different ages. The limits of normal variation from the average figures here given may be very wide. In practice it is safe to consider malnourished any child 10 or more per cent below the average, and obese any child 15 or more per cent above the average. Special or measured diets for children should supply sufficient food to maintain the body weight at a figure between 3 per cent below and 6 per cent above the average weight considered standard for the the child's height. Since children in good

health are ordinarily growing, the standard is constantly shifting and should be redetermined at least every four or six months. For while the problem of adjustment of the diet to body requirements is simpler because growth need not be considered. On the whole, it is better for the weight of most adults to be approximately that of the standard or slightly below the standard rather than much above it. This is particularly true in the case of epileptics whose tendency to overeat is a well-known symptom. The average weights of normal adults of different heights and ages are given in Tables VIII and IX.

Diet and Growth.—Growth depends in large measure upon the quantity and quality of food absorbed, and can be normal only when both quantity and quality are adapted to the needs of the individual. Since food may be eaten without being digested and absorbed it is essential that the foodstuffs chosen to make up any diet be such that they can be digested and utilized in metabolism.

Caloric Requirements of Normal Individuals.—The caloric requirements of normal individuals depend on various factors such as physical development, habits of exercise, temperament, and environmental conditions as well as upon other more readily measured factors. It is therefore impossible to determine a standard which can be rigidly employed for all persons. It is however practical to obtain figures which can be used as guides for showing the general dietary requirements. With a little experience detailed adjustment of the food intake based

upon these would-be standard figures becomes relatively simple, and quantities and proportions of the different foodstuffs can be varied from time to time to suit the reaction and habits of the individual patient. Table X shows the average caloric requirements of boys and girls at different ages. These standards correspond in general with those prepared by Lusk for the Interallied Scientific Food Commission in Paris in March 1918 (192).

It is a matter of common observation that all children of a given age have not the same degree of physical development; some are very tall and others short; some are muscular and robust, while others are thin or delicate. The food requirements of the different types of children are not identical, partly because of their different physical make-up, and partly because of their different habits of exercise. A little experience makes it possible for the physician, however, to estimate the degree to which these factors affect the caloric needs of an individual, and to make the necessary adjustments. The high-strung muscular person needs more food than a fat, logy person of the same weight (27, 31). If the height-weight standard is used (see page 96) the development of a given patient will be found to be greater or less than the average for his age. The diet can then be so regulated that he will receive the number of calories required by an individual of corresponding development, not the number required by an individual of identical age. With this determination as a working basis, the scales (for body weight) will soon indicate whether the diet is ade-

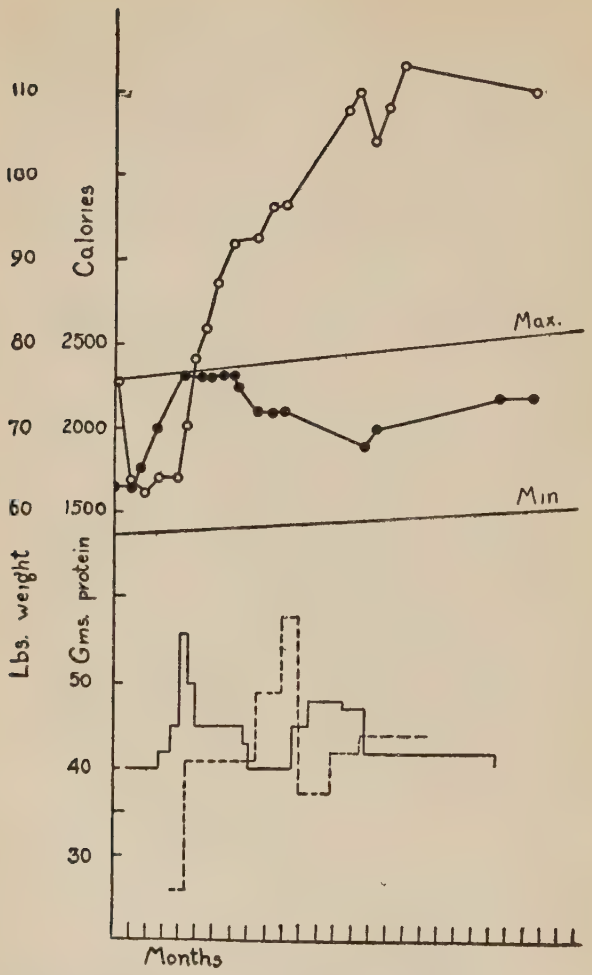

FIGURE III. (See legend on page 133).

quate, too generous, or too restricted. (See Figure III.)

That the total food needs are affected markedly by exercise and work must always be considered in the estimation of a diet. Active schoolboys, for example, who play football require more food than do those who sit at a desk and "grind" all day. The degree to which these factors affect food requirements depends in large measure on their severity. In an upper private school for boys the average necessary intake is 5126 calories, a quantity "half as much again as a farmer would require" (192). Since it is impossible to lay down any hard-and-fast rules as to the amount of food which will supply the energy expended in muscular play or work, physical status must be used as an index of the adequacy of the diet. This can be measured by recording the body weight once a week, and by care-

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FIGURE III.

The Effect of the Amount of Food Ingested upon the Body Weight. Patient B. L., a boy of 10, whose height was 56½ inches at the beginning of dietary treatment and 58 inches one year and three months later. At first there was an increase in weight, although the number of calories given was only slightly above the minimum allowance. This gain was followed by a period of stability in weight which continued until the caloric allowance was considerably increased. Thereafter the weight increased markedly.

—o——o— Weight in pounds

—●——● Calories

——⌐—— Protein intake

— — — Urinary protein.

The minimum and maximum caloric requirements are shown by the lines marked Min. and Max.

ful observation of the general well-being of the individual, both physical and mental (see Figure III). The diet should be such that the weight may be maintained within the limits already designated as normal (see page 96). When the patient is inactive the number of calories may be close to the minimum figure given in Table X and when he is active it may closely approximate the maximum figure.

The total caloric needs of adults are correspondingly greater than those of young children, but less than those of the adolescent boy. They may be calculated with considerable accuracy from the Harris, Benedict prediction tables (111) as is recommended by Joslin in the treatment of diabetics (150), or they can be roughly estimated on the basis of data given in Table XI.

The Protein Requirements of Normal Individuals.—In addition to the quantity of food contained in a diet the quality must also be considered. There has been much discussion and speculation concern-

TABLE XI

CALORIES REQUIRED DURING TWENTY-FOUR HOURS BY AN ADULT WEIGHING 70 KILOGRAMS (154 POUNDS) *

Condition	Calories per kilogram of body-weight	Calories per pound of body-weight	Total Calories
At rest	25–30	11–14	1,750–2,100
Light work	35–40	16–18	2,450–2,800
Moderate work ..	40–45	18–20	2,800–3,150
Hard work	45–60	20–27	3,150–4,200

* From Joslin, E. P.: A Diabetic Manual for the Mutual Use of Doctor and Patient. Lea and Febiger. Philadelphia and New York, 1924.

ing the protein needs of the body, and many investigations of this problem have been made, but as yet no one has accurately determined the protein needs at all ages and under all conditions of activity and inactivity. For no period of life is our knowledge of protein metabolism really satisfactory, but for childhood it is particularly inadequate. It is obvious that throughout life, protein consumption must compensate for general wear and tear, and that during childhood it must also provide material for growth. Evidence that the protein requirements of the body are closely related to age even though growth has ceased, is to be found in the fact that the young and healthy adult requires more protein than does the aged adult who is less active. Although the evidence at hand is fragmentary and does not correlate all the factors such as climate, age, muscular activity, and general health, which may greatly affect the protein requirements, enough has been learned to permit some generalization. The facts discovered have for the most part been determined by study of the protein elimination in the urine and feces of healthy individuals, and by determination of the quantity of protein needed to establish nitrogen equilibrium within the body. They indicate that in general during infancy, when the food is composed of whole milk, the needs are more than fulfilled by administration of 2 grams of protein per kilo of body weight, and that with a sufficiently large carbohydrate intake 1.5 grams per kilo are probably adequate. During childhood when the relative proportion of carbohydrate, protein, and fat is that deter-

mined by custom in this country, less protein is required than during the first months of life. One gram per kilo of body weight usually suffices at this period—a quantity which provides about 15 per cent of the total number of calories needed. No absolute standard has yet been obtained for the protein requirements of the adult. The allowance first recognized as acceptable as the result of Voit's work with laboring men (292) was 118 grams per day, a figure which Chittenden (46) considered too large after the performance of experiments upon himself. He found that he could live comfortably and maintain good health for months while his daily protein intake was reduced to between 36.6 and 40.0 grams. Lusk has more recently stated (192, p. 455) that it is "not to be denied that 50 grams of protein (containing 8 grams of nitrogen) are apparently able to maintain the adult body machine in perfect repair." "It must be, however, that more than this amount is advisable during growth or convalescence from wasting disease, or during the muscular hypertrophy which accompanies preliminary training for athletic effort."

In estimating the protein needs per unit of body weight, bodily type must be considered. Two individuals may be of the same age, sex, and height, and yet vary greatly in weight. If the protein intake of these two individuals is determined on the basis of weight it is quite evident that the obese child will receive considerably more protein than the underweight child. Since it is probable that the optimum amount of protein is the same for both these chil-

dren, it is desirable to calculate the protein intake not on the basis of the actual weight of the patient, but on the basis of the average weight (see Tables VII, VIII, IX) for the age, height, and sex in question. This will mean that the obese child receives less than 1 gram of protein per kilo and the thin child more than this amount. Since it is desirable for the obese child to lose weight and for the thin child to gain, this method of determination seems quite logical.

The degree to which variations in the temperature of the environment and other comparable conditions affect the protein needs has not been accurately determined, but most housewives and many other individuals [1] recognize that it is more comfortable to reduce the protein intake during hot weather and to increase it during cold weather. This is undoubtedly to be explained by the fact that in the oxidation of protein more heat is formed than in the oxidation of carbohydrate and fat (specific dynamic action).

Factors Which May Influence Protein Retention. —The factor which exerts the most important effect on the retention of protein is the relative proportion of protein, fat, and carbohydrate in the diet. Under normal conditions this relationship does not have to be considered, but when the food contains a very large proportion of fat and very little carbohydrate as does the ketogenic diet, the interaction of these various foodstuffs in the metabolic process is of great importance. Just how far fat can replace carbohy-

[1] I have observed this on myself. Both Folin and Lusk have made the same observations. Lusk, *loc cit.*, p. 456 *et seq.*

drate in metabolism is unknown. There is no question that it can do so to a certain extent and thus prevent inroads upon the body protein. It is very improbable, however, that it can duplicate in full the well-known protein-sparing action of carbohydrate. In order to discover the relation of a high-fat low-carbohydrate diet to protein retention the intake and

TABLE XII

EFFECT OF HIGH-FAT LOW-CARBOHYDRATE DIET ON THE RETENTION OF PROTEIN *

Ketogenic-antiketogenic ratio	Grams of F. C. P.	Urinary protein grams N×6.25	Protein balance. Stool nitrogen not included. *Grams*	Length of Period	
1:6	56 296 40	22.1 18.3 24.3	+17.9 +21.7 +15.7	5 days 5 " 5 "	No ketosis
1:2	109 177 40	28.1 26.1 26.1	+11.9 +13.9 +13.9	5 days 5 " 5 "	No ketosis
3:1	180 20 40	30.6	+9.4	5 days	Ketosis
4:1	185 6 40	37.0 28.5 37.0	+ 3.0 +11.5 + 3.0	5 days 4 " 5 "	Marked ketosis

* Not previously published.

output of protein in several epileptic patients has been determined (281). (See Table XII.) From this and other studies it has been concluded that when a diet, supplying sufficient calories to maintain body weight, contains only minimum amounts of carbohydrate (8-15 grams) 1 gram of protein per kilo of the standard or average body weight for an individual of

given height, age, and sex is usually insufficient to establish and maintain a positive protein balance. Under such conditions it is probable that a larger protein allowance is necessary. It seems likely that the requirements will be fulfilled by 1¼ grams per kilo. Peterman (234) has taken exception to this statement, without, however, presenting any data or detailed measurements to substantiate his opinion. Having no means, therefore, of confirming his claim that 2/3 gram per kilo is an adequate allowance I have no basis for changing my belief that the ketogenic diet of a child with a 3: 1 or 4: 1 ratio should contain 1¼ grams of protein per kilo of body weight.

It is quite possible that the character of protein ingested may definitely influence the retention of nitrogen. There are very few published data which bear directly on this problem in the metabolism of children. According to Mathews (205), "the quantity of protein needed is not independent of the character of the protein, since the amino-acids are the substances which are really needed, rather than the protein as such. Those proteins which contain all the amino-acids in about the same proportions as they are found in the body are probably more efficient than those which have an excess of one kind or another. Milk and meat protein replace most efficiently the protein consumed." It is said that 60 per cent of the total nitrogen in vegetable protein is wasted (194, p. 75).

Normal Mineral-Salt Requirements.—The organic constituents of food supply the materials from which the soft tissues of the body are built, while

the mineral constituents form the skeletal tissues, and the soluble salts held in solution by the fluids of the body constitute the media for many complicated metabolic processes in the body. Since the mineral substances involved in building up the body disintegrate and must be renewed, attention must be paid to the mineral-salt content of food, especially when the diet is one-sided. Even when the ordinary balanced diet is given, the mineral-salt intake should not be left to chance, because, according to Sherman (264, p. 270), "not only do the different food materials differ greatly in the absolute and relative abundance of the different elements, but the same is also true of the total food intake of different groups of people." In ordinary diets the supply of sodium, potassium, and magnesium is more than sufficient. The content of calcium, on the other hand, is often inadequate unless special attention is given to the choice of foods. (See Table XXVII.) It is estimated (264, p. 310) that the average minimal daily requirement of calcium for an adult weighing 70 kilograms is 0.45 gram of calcium (equal to 0.63 gram CaO). The amount necessary during pregnancy and lactation is greater. It was found that a normally growing child between the ages of three and thirteen years needs to absorb not less than 1 gram of calcium per day if the rate of storage is to be optimal. During infancy the requirement is 0.17 to 0.18 gram. The best storage results when calcium is supplied in the form of milk. Wang, Kern, and Kaucher (295) found in thirty-eight experimental periods, each of one week's duration, with eighteen children, that there

was a positive balance when the calcium intake (in the form of CaO) was above 0.032 gram per kilogram of body weight. They concluded that the optimum ration in a mixed diet for an eight-year-old child weighing 20 kilos would be 0.64 gram CaO per day.

The daily phosphorus requirement (264, p. 317) of adults is 0.88 gram (2.02 grams, P_2O_5) per 70 kilograms of body weight; that of children between three and thirteen years of age, 1.16-1.46 grams per day. Wang (295) found the phosphorus balance to be positive when 0.079 gram of P_2O_5 per kilo was given in the food. The optimum ration in a mixed diet for a child of eight years was concluded to be 1.58 grams P_2O_5 per day.

The influence of the various food components on the absorption of calcium and phosphorus is not completely understood. Protein probably has no influence (274), but under some conditions carbohydrate increases retention of these salts and fat diminishes their absorption. The fat-soluble vitamins, on the other hand, markedly improve the calcium and sunlight the phosphorus economy of the body.

According to Sherman (264, p. 340) 15 milligrams of food iron per day covers the iron need of the adult man. "A woman requiring eight-tenths as much food as a man will probably require more than eight-tenths as much iron, and a child requiring half as much food may easily require more than half as much iron."

Vitamins.—With discovery of the substances called vitamins, the science of nutrition entered a

new phase of development. It is unnecessary to consider in detail here this subject which is so well discussed by McCollum and Simmonds in their excellent book, "The Newer Knowledge of Nutrition" (194), but it is desirable to emphasize the fact that health, nutrition, and resistance to disease are maximal only when the vitamin needs of the body are adequately fulfilled. For any one who can take the ordinary varied diet of this country which contains abundance of fruit, vegetables, and fat the question of the vitamin intake need not be a matter of concern. When, on the other hand, the diet is restricted in some way for therapeutic purposes attention to the vitamin content of the food is essential. Particular care is necessary with a diet like that employed for ketogenic therapy. For this reason the vitamin content of most common foods is given in Table XXVIII. This will be found very useful whenever it is necessary to arrange any special or one-sided diet. It should be remembered that a suitable balance is to be maintained between the proportions of the various vitamins in the diet and that never for any length of time should any vitamin be entirely omitted.

The Basal Metabolism.—The basal metabolism of fasting normal adults has been studied by several investigators, but most thoroughly by Benedict and his coworkers (28, 30). Their studies show that during fasts and chronic under-nutrition the basal metabolic rate is materially lowered. This means that the heat production of the body is reduced partly because of loss of tissue and partly because of reduc-

tion of the activity of existing tissues. Physiologically this signifies that there is an attempt to conserve heat and tissue by reducing the metabolic rate to the minimum consistent with health. Table XIII shows that in epileptic children during fast there is a reduction of the basal metabolic rate analogous to that in the normal adult during fast (277).

TABLE XIII

THE EFFECT OF FAST ON THE BASAL HEAT PRODUCTION OF EPILEPTIC CHILDREN *

Case	Sex	Age	Post-Absorptive Metabolism	Fasting Metabolism	Days of Fast
		Yrs.	Total Cals.	Total Cals.	
P.G.	F	1½	1,306	985	8
C.P.	M	13	1,305	1,031	7
W.P.	M	11	1,425	929	14
H.A.	M	13½	1,052	978	8

* From Talbot, F. B., Dalrymple, Alice J., and Hendry, Mary F.: "Skin Temperature and Basal Metabolism During Fasting," *Am. J. Dis. Child.*, 1925, 30, 491.

In view of the fact that the administration of thyroid, which raises the metabolic rate, has been recommended in the treatment of epilepsy, it is interesting to review the results of investigations of the basal metabolism of epileptics not subject to dietary restrictions. Boothby and Sandiford (40) found that in twenty out of twenty-four epileptics the rate was normal or high. Lennox and Wright (176) in 130 adult epileptics found the basal metabolism normal in 68 per cent of individuals and 15 per cent or more below normal in 12 per cent of their cases. It was noted that in no instance was there evidence of myxedema. In an investigation by Talbot and Moriarty

(274) of the metabolism of eleven epileptic children the basal level was in all cases normal or above normal. The series of twenty-three epileptic children more recently studied by Talbot (280) showed that three had a metabolic rate of below minus 15 per cent, which can be considered definitely subnormal. From these results it can be seen that in the majority of epileptics the basal metabolism is normal or above normal, and that in only a small proportion of cases is there sufficient reduction of the basal level to justify thyroid therapy.

TABLE XIV

RESPIRATORY QUOTIENTS FOR PROTEIN, FATS, AND CARBOHYDRATES *

	Heat Produced in Oxidation of 1 gram	Respiratory Quotient $\frac{CO_2 \text{ c.c.}}{O_2 \text{ c.c.}}$
	Cals.	
Starch	4.20	1.000
Cane Sugar	3.96	1.000
Milk Sugar	3.75	1.000
Animal Fat	9.50	0.711
Protein	4.40	0.809

* Benedict and Talbot: Publication No. 201, Carnegie Institution of Washington.

The Combustion of Foods as Shown by the Respiratory Quotient.—The respiratory quotient is the ratio between the amount of oxygen consumed and the amount of carbon dioxid produced during a given interval of time. It is expressed by the formula $\frac{CO_2}{O_2}$ The respiratory quotients for protein, fat, and carbohydrate are given in Table XIV.

During inanition, when the individual subsists

largely on the fat and protein of the body tissues, the respiratory quotient is usually about 0.71. When carbohydrate in the food is used for the most part to supply the caloric needs of the body, however, it approaches 1.00. Krogh (158) has advanced the theory that when the food contains excess carbohydrate, this carbohydrate is converted into fat if the total respiratory quotient rises above 1.00; and conversely that when fat is in excess of available carbohydrate, carbohydrate is being formed if the total quotient reaches 0.71. Since protein supplies only about 15 per cent of the calories of catabolism it does not affect the respiratory quotient sufficiently to cause a serious error in the deductions drawn. DuBois (76, p. 74) recommends an ingenious chart devised by Michaelis for the rough determination of the proportion of calories derived from fat, carbohydrate, and protein with any given respiratory quotient (Figure IV). Such calculations, although useful in a certain way, are not justifiable unless measurements of the metabolism are made throughout the greater part of a twenty-four-hour day.

The average respiratory quotient of normal individuals varies with age. In infants during the first days of life (29) it has been found to be:

Days	1	2	3	4	5	6	7	8
R.Q.	0.80	0.74	0.73	0.75	0.79	0.82	0.81	0.80

Later the average figures are:

Infants under 2 years after meals	0.80-0.98
Children Post-Absorptive (2-12 years)	0.83
Men	0.83
Women	0.81

The respiratory quotient of a fasting man falls to 0.70 or below between the second and the seventh day of fast, the exact time of the drop depending

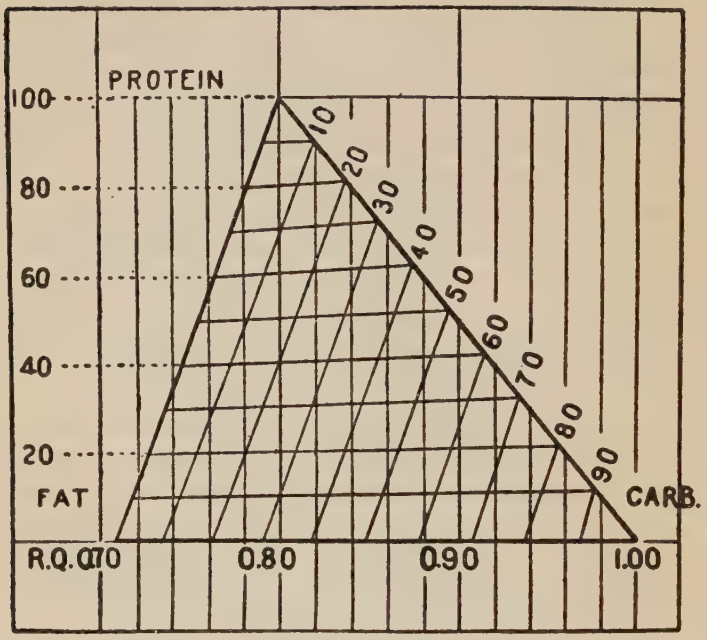


FIGURE IV.

Taken from DuBois Basal Metabolism in Health and Disease, 2nd Edition, 1927, p. 74.

Diagram showing the percentages of calories derived from protein, fat and carbohydrate according to the respiratory quotient. The base line gives the total respiratory quotient; the ordinates reading on the left-hand side give the percentage of calories from protein; the diagonals reading on the right of the triangle give the percentage from carbohydrate.

upon the size of the glycogen reserve when the fast began. All factors influencing the availability and size of the glycogen reserve are not yet known. I

have, however, unpublished data which demonstrate that it is influenced by age. The younger the child, the more rapidly is the reserve exhausted. The character of the food eaten before fasting also affects the glycogen reserve.

Daily variations in the respiratory quotient depend mainly on the amount of carbohydrate ingested. Meals containing a large proportion of this material favor rise of the respiratory quotient to approximately 1.00; while those containing little or no carbohydrate produce a less marked rise when the diet is otherwise normal. If, however, carbohydrate starvation is prolonged in children, a meal containing little or no carbohydrate may not raise the respiratory quotient at all (unpublished data).

Blood Sugar.—In the normal body a stream of sugar in the form of dextrose continually circulates in the blood and there is a reserve in the form of glycogen in the muscles and organs, particularly in the liver, which can be utilized whenever there is an extra demand. Since food elements are continuously being burned in the body, and carbohydrate constitutes by far the largest source of fuel, the amount in the body must be constantly replenished by the ingestion of food. If, for any reason, the supply or the availability of sugar or carbohydrate is reduced, the metabolism must eventually change and become adjusted to the new conditions.

The sugar (glycogen) reserve and the quantity of dextrose in the circulating blood are influenced by various factors. In general it can be said that the younger the individual the more easily can the gly-

cogen reserve be depleted. Benedict and Talbot (27, 29) in metabolic studies of infants have found variations in the respiratory quotient which they interpret as evidence that immediately after birth and during early infancy fasting is followed by exhaustion of the glycogen reserve within twenty-four hours. Other data seem to indicate that in children between eight and thirteen years of age fasting results in almost complete depletion of the reserve within two to four days; and that in adults the reserve is drained after two to five days of fasting.

The quantity of sugar circulating in the blood varies somewhat in different normal individuals. Usually between 0.08 and 0.10 milligram per 100 c.c. are present in the blood, but from time to time apparently normal persons are found whose blood habitually contains less or more than this amount. In most instances, however, overstepping of these limits is an indication of hypoglycemia or hyperglycemia.

During the day there is a normal and expected variation in the quantity of sugar in the blood. The content increases after meals, the exact speed and the extent of the increase depending largely on the amount and type of carbohydrate ingested. The content also varies with the amount of exercise taken. In epileptics the blood-sugar level is normal until an attack takes place. It may then be definitely raised (207, 180) probably on account of the muscular exertion and asphyxia involved in the seizure.

Lennox (169) investigated various factors which affect the blood-sugar curve. He found in a large

proportion of normal as well as epileptic individuals that the rise in the blood-sugar curve was progressively less marked after each injection on ingestion of sugar. He did not think this was due to the stimulating action of adrenalin which might have been elicited by excitement.

In 140 cases of epilepsy the blood-sugar curve was found to be normal in 70 per cent of individuals, above normal in 24 per cent, and below normal in 6 per cent. There was in no case evidence of abnormal carbohydrate metabolism.

The rise in the *blood-sugar curve during fast* or ketogenic therapy is much higher and more prolonged than in the same patient under normal conditions (171, 156). This hyperglycemia may be due to lack of use and stimulation of the sugar-regulating mechanism because of the fast. It does not seem to have any particular relationship to epilepsy.

The Relation Between Epileptic Seizures and the Blood Sugar.—Although there is no apparent relationship between the level of the blood sugar and epileptic seizures (see above), it has been found that in fasting patients, and those restricted to a ketogenic diet, which involves other factors, there is a general tendency for the blood-sugar content to be slightly or definitely lower than in untreated epileptics. Aside from the facts that the treated patient is clinically better, and that in some instances excess carbohydrate in the diet seems to predispose to attacks, there is no evidence of any relationship between the habitual blood-sugar level and epilepsy.

(For the relation of the carbohydrate metabolism to the body fluids, see section on Dehydration.)

A decrease in the quantity of sugar in the blood may, on the other hand, induce symptoms which simulate previous seizures in the same patient. The development of symptoms seems to depend not so much upon the actual sugar content as upon the speed with which the content is reduced. This is illustrated by the frequency which hypoglycemic symptoms appear in a few hours in diabetics who receive an overdose of insulin. The reaction may occur at a higher level when the fall in the sugar content is abrupt than when the fall takes place over a period of days, as in the case of J. B. (262) who, while fasting, did not have any symptoms until the blood sugar reached 38 milligrams per 100 c.c. on the third day after the beginning of fast, and in P. G. who had no symptoms when the blood sugar reached 46 milligrams on the sixth day of fasting. J. B.'s hypoglycemic symptoms were controlled within one-half hour by the administration of glucose.

General Theoretical Factors Involved in Ketosis.—Ketosis, which is characterized by the presence of excess acetone, β-oxybutyric and diacetic acids in the blood, results from abnormal physiological and metabolic processes. The production of this state by diet appears to be effective in the treatment of epilepsy and consequently the factors involved in ketosis are discussed. Ketosis often occurs during infections, fasting, restriction to high-fat, low-carbohy-

drate diets, diabetes mellitus, cyclic vomiting, and after etherization. Its association with such a variety of disorders makes it obvious that some general disturbance is common to all of these apparently unrelated conditions—a fact which can be clearly demonstrated by delineation of the physiological principles involved.

Acidosis.—There are two types of acidosis, which, although due to entirely different causes and easily distinguished theoretically, are in reality largely interrelated and interdependent. There is, first, a change in the acid-base balance of the body tissues caused by a shift in the relative proportions of normal acids and bases present: and second, a ketosis caused by abnormality of the fat metabolism which results in incomplete catabolism of ingested fat and consequent accumulation in the body tissues of excessive amounts of intermediary products, the ketones. Before discussing the details of acidosis and ketosis, it will be well to outline the physiological characteristics of acetone.

Physiology of Acetone.—Experiments on animals show that acetone diffuses very rapidly throughout the body from any point of injection. It appears in the breath immediately after intravenous injection, within one minute after intraperitoneal injection, and within four minutes after introduction into the stomach. Its action in this respect is comparable to that of ether.

Certain other features of the physiology of acetone have also been studied in experiments with animals. Dr. John P. Parsons has worked in my

clinic on the effect of introducing acetone in various ways (unpublished data) into the blood stream of rabbits. He found that rapid intravenous injection of approximately 1½ grams per kilo of body weight was followed by a series of symptoms resembling those of ether anesthetization: all reflexes disappeared, the muscles became relaxed, sensitivity to pain was lost, unconsciousness appeared to be complete, and the pupils of the eye dilated and ceased to react to stimulation. After larger doses, these symptoms may be followed by convulsions, retraction of the head, and finally by death. The lethal dose of acetone for rabbits is thought to be about 4.35 grams per kilo of body weight.

Salant and Kleitman (248) have studied the effect of acetone upon the *hearts* of dogs and cats. They found that injection of between 2 and 3 c.c. per kilo of a 50 per cent solution of acetone in saline solution produced a fall in blood pressure. Similar effects resulted from injection of smaller amounts of a 25 per cent solution. Recovery was prompt in most instances, but occasionally the blood pressure remained low for two or three minutes. The reduction of pressure was thought to be due to cardiac depression. It was accompanied by a corresponding diminution in the volume of the kidney as demonstrated by oncometric studies. In some concentrations acetone depressed the heart action; and in 10 per cent solution (in Ringer solution) temporarily arrested it. In all cases, even when the heart was perfused with acetone for ten minutes, recovery ensued. Not infrequently there was an after effect of stimulation.

The action of acetone on *respiration* was more striking than on the circulation. Usually the frequency and depth of respiration decreased, and apnea ensued. Cheyne-Stokes' respiration followed repeated injection of acetone in dogs. In Dr. Parsons' experiments the rabbits receiving lethal doses of acetone died from respiratory failure, their hearts continuing to beat for several minutes after breathing had stopped.

In rabbits suppression of urine followed injection of acetone and persisted, as a rule, for twenty-four hours. This may be due to the direct action of acetone in overwhelming doses on the kidney or, secondarily, to changes produced in heart action and blood pressure.

The very close relationship of acetone and sugar in the circulating blood has also been demonstrated by Dr. Parsons in his experiments with rabbits. He found that the injection of sublethal doses of acetone is followed by an increase in the sugar content of the blood. This suggests that the body reserves of glycogen are called upon to neutralize acetone. The rise in the sugar curve began between 30 and 60 minutes after injection and reached its peak about three hours after injection (see Figure V). The increase in sugar content was between 30 and 100 per cent. Recovery was gradual. In another series of experiments Dr. Parsons tested the effect of glucose injections upon rabbits which had received lethal doses of acetone. If, as soon as these animals became unconscious, a 10 per cent solution of glucose was injected, the amount varying with the body weight

of the rabbit, all symptoms of acetone intoxication disappeared within five minutes or less, and the rabbit moved about normally (Figure VI). The control rabbits in this series developed the symptoms already described, twitching, retraction of the head,

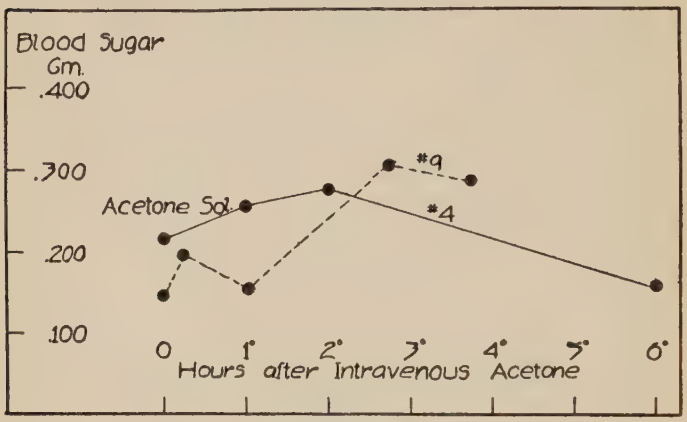


FIGURE V.

The Effect of Acetone on the Blood Sugar Content of Rabbits. Rabbit #4 which weighed 2200 grams received 2 c.c. of 4 per cent acetone solution intravenously. Rabbit #9 which weighed 3100 grams received 2¼ c.c. of the same solution. Intracardiac puncture was repeated hourly. The sugar level of the controls remained below .200 for four hours, while that of the rabbits receiving acetone rose in the curves here shown. The data here given are those of Dr. John P. Parsons and have not been previously published.

and fatal respiratory failure. These results are taken to indicate that free glucose acts specifically upon acetone. They also agree with previous observations made clinically that excess acetone is not present in the body when the food provides adequate amounts of available carbohydrate.

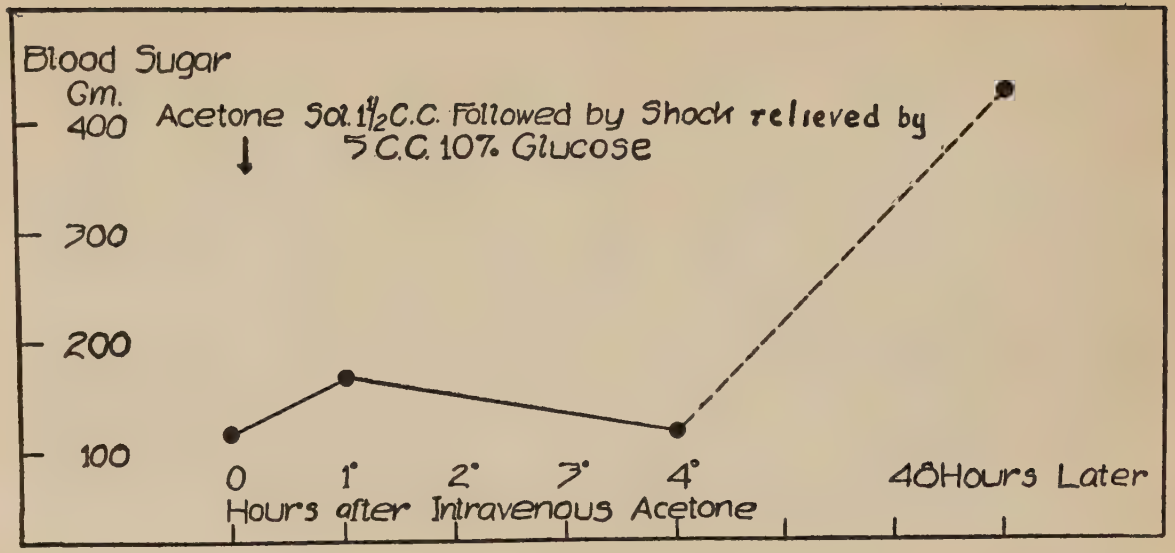


FIGURE VI.

Relief of Shock in Rabbit due to Injection of Acetone by Administration of 10 per cent Glucose Solution. Previously unpublished data of Dr. John P. Parsons.

Clinical Observations on the Effect of Carbohydrate on Ketosis.—Clear evidence of the specific action of carbohydrate on acetone can easily be found in the clinic. If a patient *fasts,* rough measurements of the breath show a marked concentration of acetone on about the third day. Simultaneous tests of the blood demonstrate a corresponding drop in its sugar content. Both these conditions persist as long as the fast continues. As soon as carbohydrate is ingested, however, for example from six to nineteen days after the beginning of fast, the concentration of acetone in the breath diminishes rapidly and within about eight hours little or no acetone is demonstrable. This is well illustrated by the case of E. G. (See Figure VII.)

The effect of a *ketogenic diet* upon the blood sugar and the formation of acetone bodies is quite comparable to that of fasting. In the case of E. G. during adherence to the ketogenic régime, as much as 16 grams of acetone were excreted in the urine within twenty-four hours. The result of altering the diet so that antiketogenic foods (*i.e.,* carbohydrates) preponderate is well shown in Table XV. During the first twenty-four hours after the addition of carbohydrate the urinary content of ketone bodies was markedly reduced, and by the second day after the change the amount of acetone in the urine was only slightly above normal limits. It can be concluded, therefore, that administration of carbohydrate to an individual who has been deprived of this food constituent for some time is followed by rapid cessation of acetone production. Just how rapid this

cessation is we do not know, but it seems probable that no acetone is formed after the administration of sufficient carbohydrate and that the excretion of acetone bodies which continues after breaking the ketogenic régime can be looked upon merely as

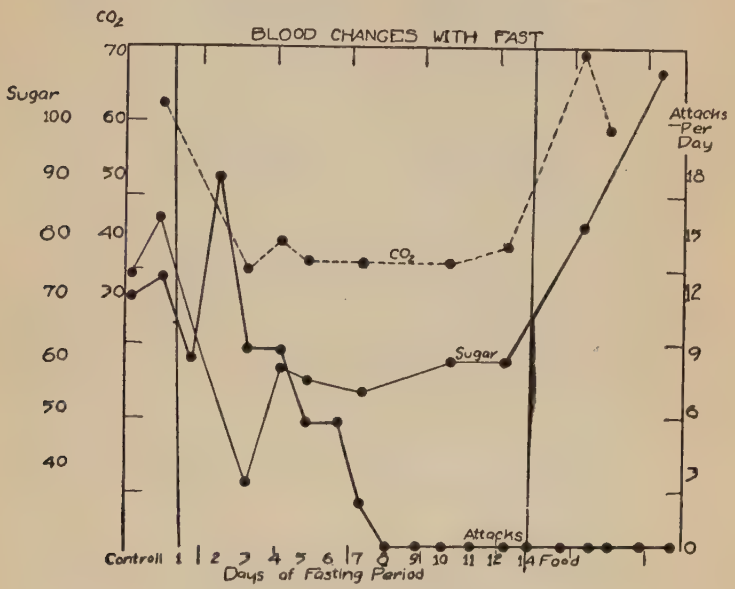


FIGURE VII.

Blood Changes during Fast. Patient E.G.

drainage of material which had previously accumulated in the tissues.

Mode of Elimination of Acetone Bodies.—Acetone is eliminated from both the breath and the urine. If the normal rate of excretion is known it should be possible to determine at least roughly the degree of ketosis by measuring the acetone output.

TABLE XV

THE EFFECT OF CARBOHYDRATE ON KETONE FORMATION AS SHOWN BY EXCRETION OF ACETONE BODIES IN BREATH, BLOOD AND URINE. TOTAL ACETONE BODIES CALCULATED AS ACETONE*

	Diet			Urine, 24 Hour Specimen, *Gm.* (Normal, 0.420)	Breath, Fasting, Appearance *Time in Seconds* (Normal, Absent)	Blood, Fasting, *Gm. per Liter* (Normal, 0.013–0.026)	Attacks (Before Diet, 40–80 Daily)
	Carbohydrate, *Gm.*	Protein, *Gm.*	Fat, *Gm.*				
On high fat diet	3	35	190	16.35	6	...	0
	3	35	190	9.27	6	...	0
	3	35	190	15.07	5	0.935	0
On high carbohydrate diet							
First 24 hours	296	40	56	1.88	140	...	0
Second 24 hours	296	40	56	0.65	210	0.144	0
Third 24 hours	296	40	56	0.46	Absent	...	0
Fourth 24 hours	296	40	56	0.80	Absent	0.052	1
Fifth 24 hours	296	40	56	0.90	Absent	...	1
Sixth 24 hours	296	40	56	0.32	Absent	...	6
Seventh 24 hours	296	40	56	0.22	Absent	...	7
							33 attacks by eleventh day

* From Talbot, F. B., Metcalf, K. M., and Moriarty, M.: "Epilepsy. Chemical Investigations of Rational Treatment by Production of Ketosis," *Am. J. Dis. Child.*, 1927, 33, 218.

And from this determination it would be possible to ascertain the effectiveness of a given diet, and the accuracy with which it is adhered to. Unfortunately, no measurements have been obtained which can be utilized as a definite and reliable scale of the degree of ketosis. Metcalf and Moriarty, using the method described by Van Slyke (291), found marked variation from day to day in the acetone concentration in the urine and in the total quantity of acetone bodies excreted in twenty-four hours. McQuarrie and Keith (196) found that the high peak of excretion was in the afternoon and the low level in the early morning hours.

Diacetic acid and β-oxybutyric acids are eliminated through the kidneys only. Magnus-Levy (200) found that the concentration of these acids was seldom above 1.5 per cent during coma and that it never rose above 0.6 per cent in non-comatous patients. In my experience, however, during ketogenic therapy the figures are somewhat higher (279).

Patient	*Dietary Ratio*	*Concentration of Acids* %
E.J.	3:1	0.8–1.3
E.G.	4:1	0.4–0.8
E.G.	5:1	0.8–1.0

Ketosis. *General Discussion.*—The acid or ketone bodies so far as they are known are β-oxybutyric acid ($CH_3CHOH—CH_2COOH$), diacetic acid (CH_3COCH_2COOH), and acetone (CH_3COCH_3). The two acids are excreted in the urine, while acetone, the

volatile member of the group, is excreted in both breath and urine. These bodies are formed under many conditions and their appearance is so frequent that acidosis can almost be said to be the commonest symptom of disease. Ketosis develops when there is insufficient carbohydrate available to permit complete combustion of fat, in diabetes mellitus, fasting, and after ether anesthesia, and severe exercise.

Understanding of the factors involved in the production of ketosis has increased greatly in the past decade. It is based largely on the work of Magnus-Levy (202), and on the more recent studies of Shaffer (255, 256, 257, 259).

Shaffer worked on the hypothesis that the property possessed by carbohydrate and other substances of preventing the appearance of ketone bodies, involved a chemical reaction in which "ketogenic" substances, mainly carbohydrate, in the food were balanced during normal health by "antiketogenic" substances. He concluded that one molecule of glucose was ketolytic for one molecule of ketogenic substance. Detailed discussion of the factors which enter into the equations involved can be found in the original articles. It is notable that fat is for the most part ketogenic and carbohydrate antiketogenic. Protein has a mixed value because its components, leucine, phenylaline, and tyrosine, are convertible into acetone bodies. They do not produce sugar. The other amino acids of which protein is built form sugar but not β-oxybutyric acid. The glycerol of fat, although present in relatively small amounts,

is a third source of antiketogenic material. It is abundant enough to affect all accurate computations of the ketogenic-antiketogenic ratio of the diet. Methods for calculating the molecular values of food have been summarized by Shaffer (255, 256, 257, 259) as follows:

Ketogenic substance expressed as gram molecules of precursors of aceto-acetic acid.

(a) 1 gram of fat $= \frac{3 \times 1}{874} = 0.00343$ mol.

(b) 1 gram of urine nitrogen $= 0.01$ mol.

Antiketogenic substance expressed as gram-molecular equivalents of glucose.

(c) 1 gram of urine nitrogen $= \frac{3.6}{180} = 0.02$ mol.

(d) 1 gram glucose from carbohydrate $= \frac{1}{180} = 0.00556$ mol.

(e) 1 gram of fat $= \frac{1}{874} \div 2 = 0.00057$ mol.

The formula $\frac{a + b}{c + d + e}$ = ketogenic-antiketogenic ratio.

or

$$\frac{2.4 \times (\text{gms. urinary protein}) + 3.43 \times (\text{gms. fat burned})}{5.56\ (\text{gms. carbohydrate burned}) + 3.2 \times (\text{gms. urinary protein}) + 0.57\ (\text{fat burned})}$$

With substitution of the ketogenic-antiketogenic values of foodstuffs according to Woodyatt's description (303) Table XVI is obtained.

Metcalf and Moriarty (278) have devised an equation, which, although neither mathematically nor scientifically accurate, is far more convenient for

TABLE XVI

PERCENTAGE OF ANTIKETOGENIC AND KETOGENIC MATERIAL IN DIFFERENT FOODSTUFFS

Foodstuffs	Antiketogenic	Ketogenic
Fat	0.10	0.90
Carbohydrate	1.00	...
Protein	0.58	0.46

general clinical use, and involves no errors larger than those which inevitably arise in computing and weighing out the diet.

$$\frac{\text{Ketogenic substance}}{\text{Antiketogenic substance}} = \text{F (Gms. fat)} : \text{C} + \text{P (carbohydrate and protein)}$$

Peterman (224) recommends the use of the following formula:

$$\text{F} = 0.101\,\text{M} - 0.216\,\text{P}$$
$$\text{C} = 0.244\,\text{M} - 2.27\,\text{F} - \text{P}$$

Effect of Fasting and the Ketogenic Diet on Metabolism. *Heat Production.*—The majority of studies of the relation between fasting and the basal metabolic rate have been made upon epileptic children and adults who were "professional fasters." Since no evidence has been found that epilepsy exerts a specific effect upon the basal metabolism, it seems justifiable to consider the two sets of data, at least in some measure comparable. Talbot, Dalrymple, and Hendry (227) found that in three of four cases studied there was a definite decrease in the total heat production of the body after a fast of from seven to fourteen days. The longer the fast in their experience the greater the decrease in the basal level. Co-

incident with slowing of the metabolic rate were changes in other body functions, the purpose of which seemed to be to conserve heat and energy; among these were lowering of the surface temperature of the body, lowering of the rectal temperature, retardation of the pulse rate, and reduction of the blood pressure. The changes are well illustrated in

TABLE XVII

THE COINCIDENT EFFECTS OF FASTING AND FEEDING UPON THE WEIGHT, THE PULSE RATE, THE BLOOD PRESSURE, THE SKIN AND RECTAL TEMPERATURE, AND THE BASAL METABOLIC RATE IN A BOY OF 11 YEARS *

Case W.P.	Wt.	Pulse	Blood Pressure	Temperature Av. Skin	Temperature Rectal	Basal Heat Production *Total Cals. Per 24 hrs.*
	Kg.			*C.*	*C.*	
Post-absorptive ..	31.36	83	120/74	34.08	38.0	1,425
14th day of fast ..	26.48	52	108/82	30.60	37.2	929

* From Talbot, F. B., Dalrymple, Alice J., and Hendry, Mary F.: "Skin Temperature and Basal Metabolism During Fasting," *Am. J. Dis. Child.*, 1925, 30, 491.

Table XVII. The effect of prolonged fasting has been studied far more thoroughly in the adult than in children. Benedict gives a very full description of the metabolic changes found in the professional faster, Levanzin (28).

Theoretically ketone acidosis should raise the basal metabolic level, but because of loss of body tissue during fasting, it is impossible to demonstrate whether or not this metabolic shift actually takes place. If the ketone acidosis develops as the result of limitation to a ketogenic diet, however, this fac-

tor of inanition is lacking and it should theoretically be possible to demonstrate conditions which are hidden in the fasting state. The basal metabolism of children with marked ketosis produced by the ketogenic diet has not been found to be changed enough to warrant any definite conclusions.

Sugar Reserve.—Although the sugar reserve has been fully discussed elsewhere, it is desirable for clarity of thought to emphasize here certain factors associated with it. The daily food intake continually furnishes a large amount of sugar which replaces that used as fuel to keep the body warm. This freshly obtained carbohydrate circulates freely in the blood and is constantly burned. If it is unnecessarily abundant, part is utilized to form the glycogen reserve; if it is deficient, the discrepancy is compensated for in so far as possible by utilization of carbohydrate which has previously been stored in the form of glycogen. That the reserve which stands ready to counterbalance dietary deficiencies markedly influences the effect of fasting and therapeutic dietary restrictions is obvious. Could it be measured definitely, the effectiveness of dietary treatment could be foretold with considerable accuracy. No means of determining the amount of the sugar reserve during life has, however, been devised except that of depleting the reserve itself.

The concentration of sugar in the circulating blood of children during fast has been studied in numerous cases in the Children's Clinic of the Massachusetts General Hospital in Boston. While the concentration decreases rapidly, there is a cor-

TABLE XVIII

EFFECT OF FASTING ON THE CONCENTRATION OF SUGAR IN THE CIRCULATING BLOOD*

The Figures Given Are Milligrams Per Hundred Cubic Centimeters of Blood

Case	Control Before Fast			Days of Fast													Control After Fast			
				1	2	3	4	5	6	7	8	9	10	11	12	13	14				
1. J.B. ...	75	74	83	..	..	38	58	55	..	53	..	..	58	..	58	Fast ended		..	81	..	108
2. W.P. ..	..	..	92	..	73	89	55	70	62	61	49	61	66	64	77	58	74	87	..	76	..
3. C.P. ...	83	..	92	..	82	68	68	..	68	59	48	57	76	56	70	68	64	95	..	85	..
4. H.A. ..	101	109	101	94	87	63	68	71	48	61	60	67	78	..	Fast ended			115	..	..	..
5. P.G. ...	..	91	..	87	73	76	74	60	46	67	50	60	53	..	Fast ended			62	90	..	74

*From Shaw, E. B., and Moriarty, M.: "Hypoglycemia and Acidosis in Fasting Children with Idiopathic Epilepsy," *Am. J. Dis. Child.*, 1924, 28, 553.

TABLE XIX

EFFECT OF FASTING ON THE RESPIRATORY QUOTIENT*

Case	Control		Days of Fast									
			1	2	3	4	5	6	7	8	9	10
4. H.A.	0.87	0.85	0.78	0.81	0.75	...	0.77	...	0.69	0.70	0.67	...
5. P.G.	...	...	0.79	...	...	0.70	...	0.70	...	0.71	...	...

*From Shaw, E. B., and Moriarty, M.: "Hypoglycemia and Acidosis in Fasting Children with Idiopathic Epilepsy," *Am. J. Dis. Child.*, 1924, 28, 553.

responding increase in the quantity of ketone bodies in the breath and urine. Simultaneously the respiratory quotient changes until it becomes that characteristic of pure fat catabolism. These conditions are well illustrated in Tables XVIII and XIX, which were compiled from figures obtained by Shaw and Moriarty (262).

In adults the blood-sugar concentration during fasting is lower than normal, but tends to be higher than in children. Lennox (167) reports that on the whole it was above 70 mgm. per 100 c.c. of blood, whereas in children the figures average below this point. The smallest concentration found in an adult was 51 milligrams; in a child, 38 milligrams. After carbohydrate was administered to break the fast, the sugar content of the blood invariably rose to normal in the investigations reported.

When the diet is restricted to ketogenic materials, the blood-sugar concentration also decreases, but less rapidly and to a less degree than during complete fasting. These differences are to be explained by the fact that even the most severe ketogenic diet contains a small quantity of carbohydrate (8 grams or more) to render the food passably appetizing. In children the lowest blood-sugar concentration found during ketogenic therapy was 57 milligrams, but the figures tended on the whole to be above rather than below 70 milligrams (279). Lennox reports that in one patient whose sugar reserve had previously been exhausted by fasting, the blood-sugar concentration did not rise after administration of a ketogenic diet. When the fat content of the food is high, the res-

piratory quotient usually becomes that characteristic of pure fat catabolism just as it does during fast.

Protein-Sparing Action of Carbohydrate.—Carbohydrate, in addition to supplying heat for the body, protects the protein of the tissues so that it can be used for other purposes than to provide energy. This function has been fully discussed by Lusk (192, p. 352) but stress should be laid upon certain points here. Since the various organs of the body are composed largely of protein, and since they must be as efficient as possible if the maximal degree of health is to be maintained, it is obvious that the rôle of protein in the bodily economy is more important than that of either fat or carbohydrate whose chief function is to supply energy. Normally, therefore, protein is conserved whenever possible, and the greater part of the necessary heat (approximately 85 per cent) is derived from fat or carbohydrate. As a source of energy, fat can replace carbohydrate only in part. As soon as ketosis develops, the ketogenic-antiketogenic ratio becomes such that the antiketogenic content of protein must be liberated unless carbohydrate can be obtained from an external source. Since traces of the ketones appear in the urine when the ketogenic-antiketogenic ratio of the food is 2: 1, and tests become definite when the ratio is 2½: 1, there is a marked diminution in the protein retention of the body throughout ketogenic therapy (see table XII).

While the food contains plenty of carbohydrate; that is, when there is no ketosis, 1 gram of protein

per kilogram of expected body weight for the given age and height (see table VII) appears to fulfill all requirements for both repair and growth in children. If, on the other hand, such a marked ketosis exists as is found on a 3: 1 diet, the urinary output of nitrogen increases, and this allowance is consequently inadequate. This has been frequently demonstrated by measurement of the nitrogen balance for three-day periods. It seems probable as the result of investigations that during intense ketosis the protein requirements of the body are not met by less than 1¼ grams of protein per kilogram of *expected body weight*. If the actual weight is used as a basis for the calculation of the protein allowance, the quantities given are usually either too large or too small. A thin child, whose weight is below average, will receive less protein than as if he had attained the average weight for his age; and conversely a fat child will receive more. It is probable that this factor accounts for the comparatively small allowance, 2/3 gram of protein per kilo, recommended by Peterman for ketogenic diets.

The minimum protein requirements of an adult who receives enough non-nitrogenous food to supply the caloric needs of the body are covered according to Chittenden (47) by 0.625-0.75 gram per kilogram of body weight. In a more conservative estimate the amounts would be a little higher (80). Certainly more is necessary for adults with prolonged dietetic ketosis just as in the case of children.

The question of the degree to which fat can replace the protein-sparing action of carbohydrate is

still under investigation and still unanswered. It seems probable, however, that fat can be successfully substituted for carbohydrate when the total caloric intake is sufficient for maintenance and growth, up to the point where it is necessary to utilize the antiketogenic components of protein, or in other words until the ketogenic-antiketogenic ratio of the diet is more than 1: 1. Although the ketone bodies do not appear in detectable amounts (sodium nitroprusside test) in the urine until the ratio is about 2: 1, it is quite probable that the antiketogenic factor in protein is called into play before that time. If the total caloric intake is deficient and there is a loss of body weight it is conceivable that additional calories given in the form of fat may exert a protein-sparing effect even during ketosis. On the other hand, as Kayser (263) has pointed out, if no change is made in a diet, except that of replacing the calories derived from carbohydrate by an equal number derived from fat, the catabolism of protein increases markedly, and there is a corresponding loss of nitrogen from the body. As soon as carbohydrate is again given to supply the number of calories in question the body begins to replace the protein which has been lost.

Relation of Diabetes and Insulin Therapy to Epilepsy.—Since an epileptic patient is usually better clinically when the carbohydrate content of his diet is restricted and the quantity of sugar available for combustion is consequently low, it is of interest to inquire whether epilepsy and diabetes are closely associated. Dr. Elliott P. Joslin in a personal com-

munication says that "among 5,091 true diabetics whom I have seen there has been no case of epilepsy." Lennox (personal communication), on the other hand, has had two patients suffering from both diabetes and epilepsy. Study of the literature has so far failed to reveal a single report of the coincidence of idiopathic epilepsy and true diabetes mellitus. This might be taken to mean that the two conditions are very rare if not compatible.

Because there seems to be, theoretically at least, some analogy between the condition of a diabetic for whom sugar is not available on account of lack of insulin, and the condition of an epileptic whose supply of available sugar has been reduced by dietary therapy, a series of observations (not yet published) has been made by Dr. Kenneth Metcalf and Miss Margaret Moriarty at the Massachusetts General Hospital in Boston. Their investigations were designed to differentiate, if possible, between the direct effects of lowering the blood sugar and those attributable to the resulting ketosis. They studied the effect of various doses of insulin on a child who received first 296 and later 177 grams of carbohydrate daily. When 24 units of insulin were given each day, the number of epileptic seizures was reduced to less than one-half of the original figure of between 22 and 33 attacks in twenty-four hours. Increasing the dose to 54 units resulted in no further improvement, and no appreciable change in the sugar content of the blood during fasting. This was found to be between 81 and 98 milligrams per 100 c.c. in six instances and 72 milligrams in one in-

stance. Administration of 66 units of insulin in small doses throughout the day was followed by a sudden fall of the blood-sugar content to 39 mgm. per 100 c.c., the onset of hypoglycemic symptoms, and a continuous series of convulsive attacks. These symptoms were rapidly relieved when 20 grams of glucose were given by mouth. The study suggests, therefore, that hypoglycemia severe enough to produce a reaction is not beneficial in the treatment of epilepsy.

Relation Between Fasting, Ketosis, and the Mineral Salts of the Body.—Any procedure which causes a change in the normal physiology of the body may affect not only one part of the metabolic processes, but also secondarily other parts of the very complicated and interrelated system. It is therefore necessary to consider how fasting and ketosis may affect the mineral metabolism. Gamble, Ross, and Tisdale (100) studied the metabolism of the fixed base in the body during fast and obtained evidence of a definite reduction of both body water and plasma bicarbonate which were referable to acetone formation. There was considerable decrease also in the concentration of blood chloride.

Calcium and Phosphorus.—Various studies have been made of calcium and phosphorus metabolism during normal feeding and fasting. Nelson (218) found that in three children both calcium and phosphorus were retained when the diet was normal and the intake of these salts was respectively between 1.0-1.1 and 1.2-1.4 grams. When the same children received a ketogenic diet (ratio, 2½:1) the intake

of both calcium and phosphorus was reduced to approximately one-half and the balance of these salts became negative. Whether this change is attributable entirely to the reduced intake, as might be expected, or in part to ketosis is difficult to determine. About all that is known definitely is that when the diet is normal the balance is positive and more calcium and phosphorus is excreted in the feces than in the urine; and that when the ketogenic diet is used the mineral intake is reduced, the mineral-salt balance is negative, and more calcium and phosphorus are excreted in the urine than in the feces. The shift of the mineral-salt balance from positive to negative must not be lightly regarded in the management of ketogenic therapy, for under prolonged treatment there might be serious danger of de-mineralization of the body.

That this danger may perhaps be less serious than the studies just quoted would suggest, however, is indicated by the condition of the long bones of one of twelve children who had been submitted to ketogenic therapy more or less continuously for about two years. X-ray photographs were thought by the Roentgenologist to reveal abnormally great calcification. This observation lends some support to the warning which Joslin has repeatedly given in regard to the development of arteriosclerosis as the result of prolonged ketosis in diabetes mellitus, although in this child there were no arterial abnormalities. Theoretically, it seems impossible that ketosis should favor the development of arteriosclerosis; and actually I do not know of a single

instance in which this anomaly has been known to follow ketogenic therapy. Repeated determinations of the blood pressure of the children under my care have failed to reveal evidence of any changes in the arteries.

Under both normal and ketogenic conditions the concentration of calcium and phosphorus in the blood was the same in Nelson's experience. A similar observation has been made in the study of 30 epileptic patients in the Children's Clinic of the Massachusetts General Hospital. The concentration of calcium in their blood on entrance to the hospital was between 8.7 and 12.5 mgm. per 100 c.c. Later, after the induction of ketosis by dietary therapy, the concentration was found to be unchanged. This cannot be interpreted as evidence that the calcium balance of these patients was unaltered, however, as can be seen from the results of Nelson's investigations. Miss Margaret Moriarty has studied the concentration of phosphorus in the blood of seven individuals before and during ketosis. She found that before dietary therapy the concentration ranged from 3.2 to 5.5 mgm. per 100 c.c. of blood; and that during treatment it ranged from 2.1 to 5.8 milligrams. These figures are not sufficiently consistent to justify the conclusion that ketosis reduces the phosphorus content of the blood.

There is little available evidence to show whether or not epilepsy itself affects the mineral content of the blood. Dr. F. Gorham Brigham (personal communication) reports that among his adult patients with epilepsy, he has seen two whose blood-calcium

content was definitely low. Both of these individuals responded favorably to the administration of calcium. It should be remembered in this connection that when the blood calcium becomes markedly depressed the symptoms of tetany appear. These, while sometimes confused with those of epilepsy, have an entirely different etiology.

Acidosis.—Two mechanisms suffice under ordinary conditions to keep the acid-base equilibrium of the body comparatively uniform. One of these, excretion, need not here be discussed in detail, but the other, the action of the body bases upon the end products of metabolism, is so closely connected with the dietary treatment of epilepsy as to have great bearing on the practical aspects of therapy. Carbon dioxid is constantly produced within the tissues as a normal end product of the combustion of food, and is normally taken care of by excretion and by combination with sodium bicarbonate and other body bases. If unusual acids or very large amounts of normal acids are formed within the body, if the rate of excretion is retarded, if acids are absorbed in large quantities, or if the alkali reserve of the tissues has been subjected to an unusually severe drain, the acid-base equilibrium of the body shifts toward the acid side. This does not mean that the reaction (P_h) of the blood actually becomes acid, but that it becomes *less alkaline*. True acidity of the blood is incompatible with life. In a preceding section the type of acidosis known as ketosis has been discussed and defined as the condition which results when the diet contains insufficient carbo-

hydrate to permit complete combustion of fat. The consequent accumulation of abnormal acids which may combine with the free bases of the body prevents combination of these protective substances with the acids, particularly carbon dioxid, which normally form in the tissues. This is but one type of acidosis. According to Henderson (115) "any modification of the normal equilibrium between acids and bases within the organism whereby the power to neutralize acid is diminished is to be regarded as a condition of acidosis."

The relation of acidosis to epilepsy and its treatment has received much attention (180) because of the fact that epileptic seizures frequently diminish or cease when ketosis has been induced in some way. Comparatively little is definitely known, however, about the association of specific anomalies of the P_h of the blood with epilepsy. Geyelin (106) and others conclude from their studies that the acid-base equilibrium (P_h) of the blood of epileptics is less stable than that of normal individuals, but no evidence has been obtained of other differences. Gamble and Hamilton (102) found a marked increase in the total quantity of acid excreted during periods of attacks and a corresponding increase in the excretion of total fixed base. Experiments have been carried out to demonstrate, if possible, whether acidosis acts specifically to counteract some condition which produces seizures, or whether another factor associated with it is essentially responsible for the therapeutic effect.

Wilder in 1921 (299) stated that *ketosis* and not merely *any form of acidosis* exerts the therapeutic effect. This has been questioned by many investigators (180) and efforts have been made to determine whether seizures can be inhibited by production of *inorganic acidosis*. The results of these studies are not sufficiently clear cut to justify the drawing of definite conclusions, for the effect of ketosis was not entirely absent. In two cases reported by Cobb and Lennox (180), *i.e.* H. G. and D. T., there seemed to be some relationship between the attacks and the quantity of bicarbonate present in the blood, but attacks ceased only during periods of ketosis. In one of their patients, on the other hand (L. R.), $CaCl_2$ and NH_4Cl reduced the seizures as effectively as did fasting—a condition which induces ketosis. It may be that the condition of inorganic acidosis was not continued sufficiently long or was not sufficiently severe completely to stop attacks in the other patients. Be this as it may, they conclude that "seizures are not a function of blood P_h," and "that there is not a compensatory increase of seizures after a period of ketosis. It would seem that ketosis induced by a high-fat diet offers the most practical way of artificially controlling seizures." In the writer's clinic, various attempts were made to induce acidosis without ketosis in children. Potassium borotartrate (203, 204) neither controlled the symptoms nor gave any evidence of acidosis, and hydrochloric-acid milk did not cause any clinical improvement. Present evidence, therefore, seems to indicate that acidosis as distinct from ketosis has no direct cura-

tive action in epilepsy. It is possible, however, that it may have a secondary influence which enhances the therapeutic action of ketosis.

Alkalosis.—Alkalosis is the opposite of acidosis; that is, a shift of the acid-base equilibrium of the tissues toward the alkaline side. Its relation to epileptic seizures has been the subject of numerous studies (180) some of which have led to the report that administration of alkali is followed by an increase in the number of convulsive attacks. Lennox (180) outlines the case of H. G. in whom on two occasions the frequency of seizures increased markedly when alkali was administered at the end of a period of induced acidosis. In my own clinic, on the contrary, in a few children studied, alkaline therapy was not associated with an increase in the number of seizures. Although all factors involved have not yet been investigated, it seems probable that alkalosis, *per se,* does not directly affect the epileptic seizure. It does, however, exert a direct influence on the development of at least one type of tetany with convulsive symptoms, and appears to be its main cause. Closely associated with the convulsions of tetany is the calcium metabolism which in turn is greatly affected by shifts in the acid-base equilibrium of the tissues. Confusion of epileptic and tetanic convulsions may frequently be avoided, by bearing in mind that in tetany there is a characteristic increase in the carbon dioxid combining power of the blood (occasionally to 70 vols. per cent) which indicates that the blood content of bicarbonate has increased. Coincident with this there is a decrease

in the concentration of blood chlorides. From the available data I feel justified in concluding that when convulsions and alkalosis appear to be definitely associated the condition is not solely epileptic, but is either tetany alone, or a combination of tetany and epilepsy. This conclusion must not, however, be taken as final, for recent investigations of the physiology of the kidney have revealed that under some circumstances alkalies tend to diminish and acids to increase the rate of excretion of water from the body. As will be seen in a discussion which follows, the degree of dehydration of the tissues is considered by some physicians to be intimately related to the onset of epileptic convulsions. The various means of controlling it are assuming an interesting place among the methods of epileptic therapy now in vogue in this country. Consequently, it may perhaps eventually be found that alkalosis bears a closer relation to the epileptic seizure than has been believed.

It has been shown that hyperpnea or increased ventilation of the lungs can wash so much carbon dioxid out of the body as to induce tetany. Many authors (180) utilize this fact as a test to discover the ease with which convulsions can be induced in epileptic patients. In different experiments a varying percentage of the individuals so tested reacted to voluntary hyperpnea with a seizure or its equivalent. Sterling (180) found that attacks were induced in 30 per cent of 200 epileptics so tested, while no convulsions developed in 100 normal individuals tested as a control.

Oxygen Consumption.—The principal studies of the oxygen consumption of epileptics have been made by Lennox (180, p. 125, 11) who concludes that "it is probable that anoxemia and possibly other related chemical changes in nervous tissues play a part in inducing seizures." That this is not due solely to anoxemia is shown by the fact that a much more severe degree of anoxemia is necessary to cause unconsciousness and twitching in normal individuals (251). The possible relation between the capillary circulation of the brain and anoxemia is now receiving considerable attention. This field of investigation has been barely touched and offers many possibilities in the advance of our knowledge. (See page 39.)

Rebreathing.—Lennox has also worked on the effect of rebreathing (180, p. 129) and found that over-ventilation does not evoke seizures if the respired air contains a high percentage of carbon dioxid. In one of his patients clonic convulsions could be controlled and stopped by the rebreathing of air which contained an increasing concentration of carbon dioxid.

Dehydration.—The human body is composed in large part of water, which keeps the various elements of the body in solution, transports food to the tissues, and carries the waste products to be excreted. At different ages the proportion of water to other elements varies: normally the body of a new-born infant contains between 66 and 71 per cent; that of an adult about 56 and 65 per cent. The exact proportion present in the body at any given time de-

pends partly on the ratio between intake and output of fluid, and can be regulated within limits in so far as these two factors can be controlled. Dehydration results whenever the fluid intake is less than the fluid output.

Water enters the body through the alimentary canal normally after being ingested by mouth. It is, however, absorbed by all parts of the alimentary tract, and can, if necessary, be injected into the lower part of the tract through the rectum. The sources of water for the body are the fluids ingested, such as water itself, milk, which contains about 85 per cent of water, and soups and various beverages; solid foods, practically none of which are entirely free from water and some of which, *e.g.*, fruits and vegetables, contain a great deal; and finally the chemical processes of metabolism in which carbon dioxid and water are the end products. The proportion of liquid derived from these different sources varies greatly. The exact quantity of fluid ingested as such can, of course, be measured. The average water content of the various common foods can be found by consulting Table XXII. It will be found that toast, dried cereals, and crackers provide at best only a small amount of liquid. The quantity of water formed in the chemical processes of metabolism can be determined only by very complicated calorimetric methods (268) and is relatively small under normal conditions.

Water is excreted through more channels than it is absorbed. It leaves the body through the kidneys, the intestines, the lungs, and the skin. Under nor-

mal conditions, by far the greater part is excreted through the kidneys, but a significant and often unnoticed excretion takes place constantly from the lungs. A rough measurement of the fluid output of the body may be obtained by measuring the volume of the urine, but if there is excessive sweating or diarrhea, account must be taken of the water which leaves the body through the skin and alimentary tract. The writer once lost 4 per cent of his body weight in the perspiration due to heavy exercise. This is, however, unusual. In certain disorders of the digestive tract which cause diarrhea serious dehydration of the body may result, although ordinarily the feces contain comparatively little fluid. Although 60 per cent of the water is excreted through the kidneys and only 6 per cent through the intestine, changes in diet may change this ratio definitely. Bran for example can increase the fluid content of the stool at the expense of the urinary output of fluid. The water which leaves the body through the lungs, together with that which is excreted unnoticed from the skin, about 33 per cent of the total amount excreted, is known as the "insensible perspiration."

Whenever the quantity of fluid excreted is greater than the fluid intake, dehydration results. This may occur in the febrile diseases, fasting, with a limited fluid intake, a low-carbohydrate high-fat diet, acidosis, with the use of effective diuretics such as urea, or with hypertonic salts or glucose solutions, and magnesium sulphate. It also occurs in diarrhea and in intense sweating. Acute dehydration may be

accompanied by fever which is quickly relieved by water.

The normal fluid intake is between 38 and 48 ounces of liquid a day. The urine then has a specific gravity of about 1.012. If the fluid intake is doubled the specific gravity may be as low as 1.004 and if decreased to 12 or 13 ounces may rise to between 1.030 and 1.040.

The level of the water balance depends upon the many factors suggested above, but the kidney, through which two-thirds of the excreted water normally passes, is the most important organ concerned. Upon its function and the factors which influence it, will depend in large part whether water is retained or lost from the body. Many other complicated internal factors also influence the amount of water retained in the body or body fluid. These have been well summarized by Gamble (103). Body fluid is distributed as follows: (a) in the blood, (b) in the cells, and (c) in the remaining spaces between the blood and the cells. Edema is localized in the latter "interstitial" spaces. The metabolism of the mineral salts has a marked effect on the body fluids. A sodium deficit, for example, may result in loss of body water. Other intricate factors, either independently or in relation to one another, have a marked influence on the water metabolism. For example, an excessive amount of carbohydrate in the food is believed to increase the body water.

The possible relationship of secretion or retention of excess fluid within the skull to epileptic seizures has attracted the attention of many investigators,

some of whom now look upon dehydration as a therapeutic agent for the control of epileptic attacks. Temple Fay of Philadelphia (84), who is the chief proponent and advocate of this method of treatment, has written a comprehensive outline of the basis of his theories and the facts upon which his opinions are based. In brief, he states that ever since the time of Hippocrates a "moist" brain has been associated with epilepsy, and that attention has been drawn to this fact again and again. William Alexander in 1889 (3) emphasized this feature of epilepsy, and more recently Foster Kennedy, Foerster, Dandy, and Kocher have laid stress upon it (84, 271). Failure to find this "moist" condition or abnormally large amounts of fluid over the cortex of the brain at autopsy he explains as the result of post-mortem changes. The condition has recently been recognized and noted during operations on the skull or brain and has been demonstrated by means of encephalography when the cerebrospinal fluid is replaced by air. Fay states after studying 59 cases that there is probably characteristic encephalographic evidence of this condition and says that "there is no doubt about the gross changes present in many of the so-called symptomatic epileptics following trauma, inflammation, tumor, or degeneration, and in those cases where the diagnosis has been "essential" or "idiopathic" epilepsy, the attacks having been present over a period of years, a definite change can be demonstrated in the fluid pathways." He finds associated with this accumulation of fluid an increase in pressure in the cerebrospinal

pathways from the normal of about 8 mm. of Hg. to 11.2 mm. Hg. There is a difference of opinion as to whether the accumulation of fluid is primary or secondary and accidental (66). Fay and Strecker (271) base their arguments in favor of a relation between the mechanical effect of fluid and the convulsive seizures upon the premise that it is primary. This view is strengthened by the clinical evidence of cessation of convulsions when pressure is relieved by operation and lumbar puncture. Data are also presented which indicate that in many cases accumulation of fluid results from disturbance of function of the Pacchionian bodies through which the cerebrospinal fluid is believed to be absorbed (84).

McQuarrie (198) has made an interesting contribution to the problem based on the factors in the metabolism connected with the loss of water from the body. The major portion of the decrease in body weight during fasting is due to loss of water (99,100). Stark in 1769 (192) showed that diets high in fat and low in carbohydrate have a dehydrating effect, and since that time additional evidence has come to light in favor of this observation (26, p. 224).

McQuarrie concludes from his carefully studied cases that there appears to be a tendency for the epileptic subject to retain water during the active phase of the disease in amounts that are harmful; that convulsions tend to occur when a water balance above a certain magnitude is established, and after diuresis convulsions seem to be prevented. He found that a sudden increase in the water intake is followed by recurrence of seizures in the severe cases. The fol-

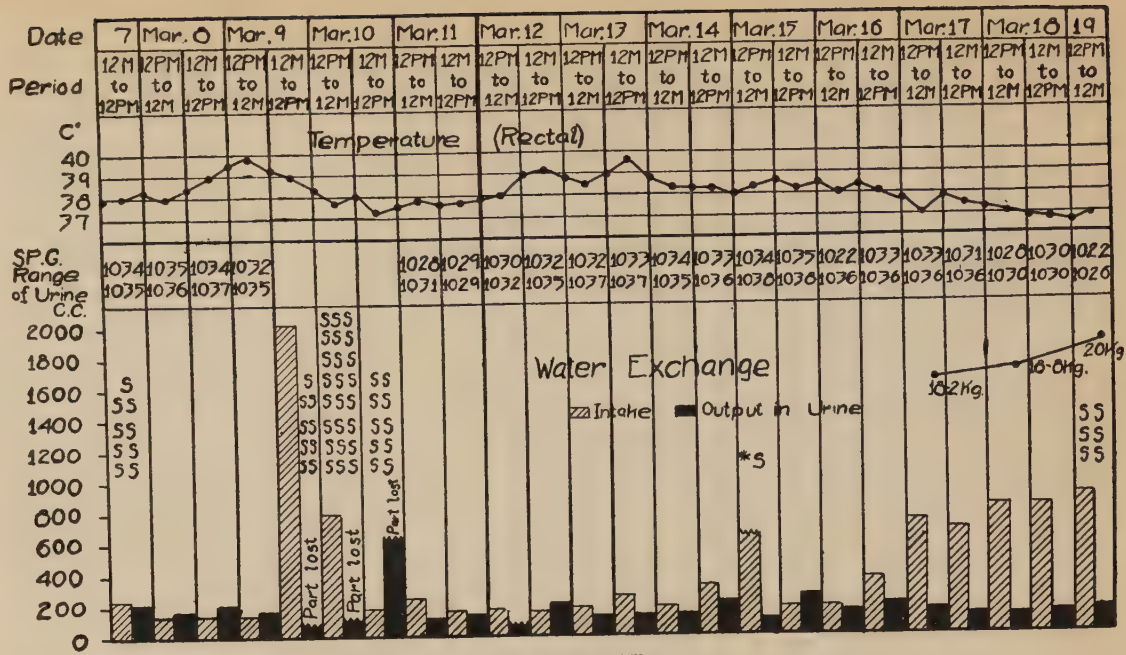


FIGURE VIII.

Effects of Variations in the Water Intake on the Occurrence of Epileptic Seizures in W. P. A borderline, non-ketogenic diet was employed up to the nineteenth twelve-hour period; a mildly ketogenic diet thereafter. The asterisk indicates the time of administration of a large soap-suds enema. S = seizure. The figure is taken from McQuarrie, I; Epilepsy in Children, Am. Jour. Dis. Children, 1929, xxxviii, p. 454.

lowing case of McQuarrie's illustrates the effects of dehydration, Patient W. P., a boy of 6, was having from ten to thirty convulsions daily for a period of nearly two weeks in spite of fairly vigorous anti-epileptic medication. Fluids had been forced during portions of this period. The onset, nine months previous, had been ushered in by attacks of petit mal followed two months later by typical convulsions. These had been treated with moderate success with phenobarbitol. The patient was physically and mentally normal.

The water intake was reduced to about 200 c.c. (6 2/3 ounces) daily and this was followed by dehydration fever, the temperature rising to 40° C. (104° F.). Because of the fever 2000 c.c. of water were given in the next twelve hours. This was followed by a fall in the temperature and a great increase in the number of seizures. (See Figure VIII.) Rigid restriction of fluid was then followed by cessation of seizures.

CHAPTER XIII

Summary of Theories of Dietetic Treatment of Seizures

Low-Protein Diets.—An apparent association of dietary indiscretions and digestive upsets (constipation, indigestion) with epilepsy has led clinicians to attribute seizures to the toxic products of protein decomposition. These were thought to be absorbed from the intestinal canal and directly or indirectly to bring about attacks. In the words of Eustace Smith (267): "It is a generally recognized fact that an abundant meat diet is injurious to epileptics, for the brain tissue which it helps to build up is of a more highly irritable composition than if a less stimulating dietary were enjoyed. Butcher's meat must be taken sparingly, and the food should consist principally of milk, vegetables, poultry, game, and fish." It is probable that when such advice is strictly followed the total amount of food is also reduced. Although limitation of the protein intake and especially that of red meat is sometimes beneficial, it is so often ineffective therapeutically that observers have recognized that the low-protein diet is not a suitable form of treatment for the cure of epilepsy.

Low-Salt Diets.—Charles Richet in 1900 recommended deprivation of chlorides in the treatment of

epilepsy. It is now generally believed that limitation of salts is a useless procedure. It should be remembered, however, that sodium chloride has a definite influence on water retention and thus is a factor to be considered in dehydration.

Acidosis.—Various investigators have tried to show that the epileptiform attacks are preceded or accompanied by relative alkalosis and have obtained experimental data to support their view. They recommend treatment by acids to counteract the supposed tendency toward alkalinity. More critical examination of the data and further research has, however, shown either that the methods used are open to criticism or that the conditions observed are also associated with non-epileptic disorders. It is probable that the alkalosis and acidosis in the cause and cure of epilepsy is accidental and depends on some irrelevant factor.

Ketosis.—Fasting was originally employed therapeutically as a means of removing from the intestines toxic bodies which might have accumulated there. These substances were believed theoretically to cause epileptic attacks, and physicians hoped by continued or frequent fasting to cure the epileptic condition. After it was found by chemical examination of the blood and excreta of fasting epileptics that ketosis existed whenever the symptoms improved, interest came to center on the ketosis rather than on the intestinal effects of lack of food. Attempts were then made to discover a scientific explanation for the clinical findings. To permit more prolonged maintenance of a state of ketosis, Wilder (299) devised a diet

upon which it was possible, although not agreeable, to live for a considerable length of time without interruptions of the ketosis. He believed as the result of his studies that the beneficial effects were due to the anesthetic action of acetone. Other investigators presented proof which apparently explained the improvement as the result of acidosis. More recently acquired data appear to refer the effectiveness of ketosis to associated changes in the quantity of fluid present in the body tissues.

Dehydration.—Dehydration is used in the treatment of epilepsy on the theory that the presence of excess fluid in the central nervous system is in some way responsible for the seizures; and that consequently drying out the body will reduce the amount of this fluid until mechanical pressure of the brain is relieved sufficiently to permit cessation of symptoms.

Summary.—The effects of the various types of dietetic treatment have been tabulated in Table XX which shows the points common to the different methods of treatment. The one effect produced by all the types of treatment used, except that of restricting the protein intake, is dehydration of the body tissues. The cause of this change differs, however, with each therapeutic method. Since common table salt favors retention of water in the tissues, reduction of the salt intake is naturally followed by decreased retention of water. Acidosis produces its effect probably by stimulating the action of the kidneys and thus increasing the fluid output. During a fast there is reduction of the fluid intake and consequent decrease in the quantity of body fluid. The

TABLE XX

COMPARATIVE EFFECTS OF VARIOUS TYPES OF DIETARY TREATMENT *

	Administration of Sedative Drugs, as Bromides, or Luminal	Low Protein Diet	Administration of Cathartics or Laxatives	Removal of Foci of Infection	Low Sodium Chloride Intake	Fasting	High-Fat Low-Carbohydrate (Ketogenic) Diet	Feeding Acidophilus Bacilli	Low Fluid Intake
Sedative Action (Nervous System)	+ +	0	0	0?	0	+ +	+ +	0	0
Lowered Total Metabolism	+	+	0	0	0	+ +	0	0	0
Predominance of Fat Combustion	0	0	0	0	0	+	+ +	0	0
Lowered Nitrogen Metabolism	0	+	0	0	0	+?	0	0	0
Lipemia	0	0	0	0	0	+	+	0	0
Lowered Glycogen Store	0	0	0	0	0	+ +	+ +	0	0
Hypoglycemia	0	0	0	0	0	+	+	0	0
Conservation of Kidney Function	0	+	+	0?	+	+	0	0	0
Reduced Salt Content of Body	0	0	+	0	+ +	+	0	0	0
Acidosis	0	0	0	0	0	+	+ +	0	0
Less issue Fluids	0	0	+ +	0?	+ +	+	+	0	+ +
Blood Chemistry Shows Little Diurnal Variation	0	+	0	0	0	+ +	0?	0	0
Bacteria of Intestines Diminished or Flora Changed	0	0?	+ +	0?	0	+ +	+	+	0

* Higgins, Harold L.: (unpublished data).

ketogenic diet so alters the metabolism as to diminish the amount of water in the tissues if the régime is prolonged. This is the reverse of what happens with a diet rich in carbohydrate which favors retention of water. Catharsis with salts temporarily increases the excretion of water through the intestines and thus presumably diminishes the fluid content of the body. The chief result of limitation of the liquid intake is dehydration. Whether the dehydration associated with the ketogenic régime is the important therapeutic factor, or whether the effectiveness of ketosis is to be ascribed to some unknown or unrecognized factor, has not yet been demonstrated. About all that can be said therefore in conclusion is that the ketogenic diet appears to be the most effective form of the dietetic treatment of epilepsy.

CHAPTER XIV

Clinical Results of Fasting

The first mention of fasting in the treatment of epilepsy appears in the Bible (Mark IX, 17-29). An epileptic boy was brought to Christ, who cast out the evil spirit which was tormenting him. When asked by His disciples why they were unable to do the same thing, Christ replied, "This kind can come forth by nothing but prayer and *fasting*."

Lennox and Cobb (180, p. 130) report that fasting is said to have been used in the treatment of epilepsy in New England fifty to seventy-five years ago. In 1910 Guelpa and Marie (110) subjected twenty patients to a fast for four-day periods with inconclusive results. Conklin, an osteopath, employed fasting therapy for "hundreds of patients," and in his one article published in 1922 (53) reports very favorable results. The 127 records of his patients seen by Lennox and Cobb proved, however, to be incomplete and these authors sum up his findings by saying that "in about 22 per cent seizures had been absent since the fast; in the remainder, about one-half of the total number fasted, there had been some improvement in symptoms. If the total number of treated patients were included, the results would not have been so favorable." There is considerable doubt as to

whether the records kept would bear critical evaluation of the effectiveness of treatment. The majority of patients who have submitted to therapeutic fasts in the last decade (105, 177, 121, 262, 276, 107, 153, 252, 265, 298) are reported to have improved during the fast and often to have been free from attacks. With few exceptions the attacks returned, however, sooner or later after food was again taken and there was no lasting benefit. In the seventeen children whom the author treated by fasting the attacks returned within two weeks and sometimes immediately after cessation of the fast. One patient was deprived of food for five different periods; the symptoms stopped completely during each, but returned rapidly after food was given. This patient is of particular interest because when a ketosis was produced by a high-fat low-carbohydrate diet and maintained for several months, the seizures disappeared apparently for good. Fasting in the treatment of epilepsy has been discarded by most investigators because it does not give permanent results. It is sometimes used to reinforce other methods of treatment.

Clinical Results of Inorganic Acidosis.—The treatment of epilepsy by the administration of inorganic acids which increase the acidity of the blood has been tried in several clinics without results justifying its continuance. Bigwood (33) and Lennox (172) noticed a reduction in the frequency of symptoms following the ingestion of acid salts. Potassium borotartrate, recommended by Marie, has been used, however, by Geyelin, Cobb and Lennox, and Talbot in their respective clinics without favorable results.

At times it appeared to diminish the severity of symptoms, but it never stopped the attacks, and could not be found to increase the acidity of the blood.

Clinical Results of Dehydration.—The theory of dehydration therapy has already been discussed in brief, but it will be of interest to mention here the results of the few clinical reports of this type of treatment which have appeared in the literature. Strecker and Fay (271) have limited the fluid intake of nineteen patients with grand mal in whom other means of treatment had failed: of these six have been free from seizures for over eight months; seven are still under control with periods of freedom from attacks which are not considered sufficiently long to justify the drawing of conclusions, and six patients have either failed to coöperate or have abandoned treatment. Of the successful cases one has been free from seizures thirteen months and another fifteen months. Fay (85) says that the patient reported free for fifteen months has now gone two and one-half years with three major attacks in this time as compared to two years of grand-mal seizures averaging twenty-five a month. McQuarrie (198) and Bauer (24) both report successful cases in children. If equally good results are obtained with larger numbers of patients, dehydration will come to be considered an important method of treating epilepsy. My own small experience with two patients has been less encouraging.

CHAPTER XV

Clinical Results of the Ketogenic Diet

Certain physiological changes which take place in the blood chemistry during restriction to a ketogenic diet are the same as those which accompany fasting. Careful investigations have shown that during the period of freedom from seizures when the patient is fasting the sugar content of the blood is low, acetone bodies are present in increased quantities in both the breath and urine, the carbon-dioxid combining power of the blood is diminished, and the P_h of the blood is slightly reduced. The quantity of non-protein nitrogen or amino-acid in the blood remains within normal limits. The increase in concentration of uric acid appears to be independent of the various changes enumerated above.

Since ketosis with its beneficial effect cannot be continued indefinitely when it is produced by fasting, Wilder, as has already been mentioned, devised a so-called "ketogenic diet" upon which it is possible to live for long periods of time (299). This was used in caring for children at the Mayo Clinic. The work was continued by Peterman (224) and later by Helmholz (113). In the Children's Department of the Massachusetts General Hospital, studies were made by Talbot, Metcalf, and Moriarty (278, 279) of the chemi-

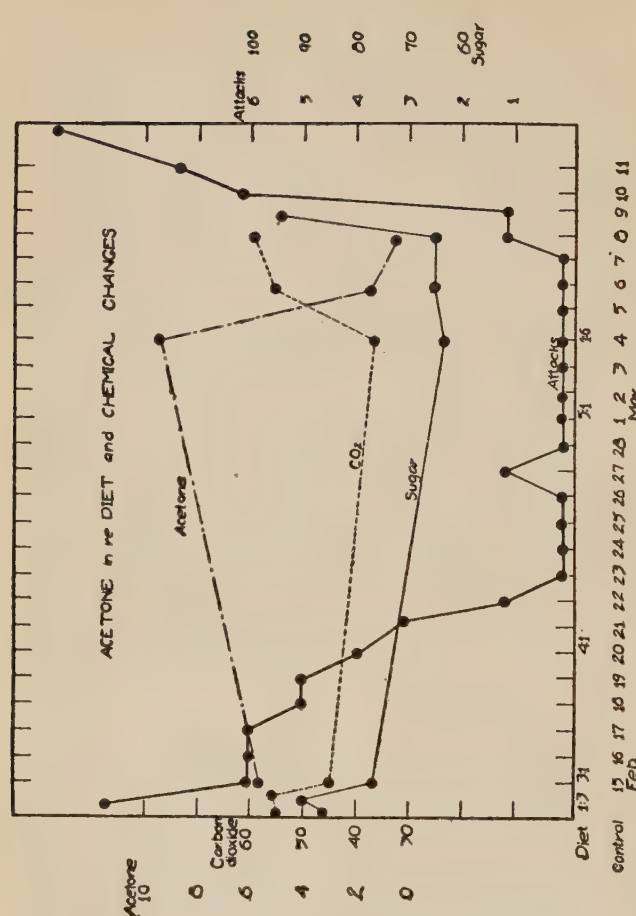

ACETONE in re DIET and CHEMICAL CHANGES
Acetone
CO2
Sugar
Attacks
Acetone 10
Carbon dioxide 60
Sugar
Diet 17 31
Control 12 16 17 18 19 20 21 22 23 24 25 26 27 28 1 2 3 4 5 6 7 8 9 10 11
Feb
Mar.

FIGURE IX.

Incidence of Attacks in Relation to Dietary Ratios and Blood Chemistry. Talbot, Metcalf and Moriarty: Boston Med. & Surg. Jour., 1927, cxcvi, 89.

cal changes which take place in the body during ketogenic therapy and the results were compared with those found during fast, often in the same subjects. The changes were found to be almost identical, except that they were less marked during ketogenic dieting than during fast. (See Figures IX and X.)

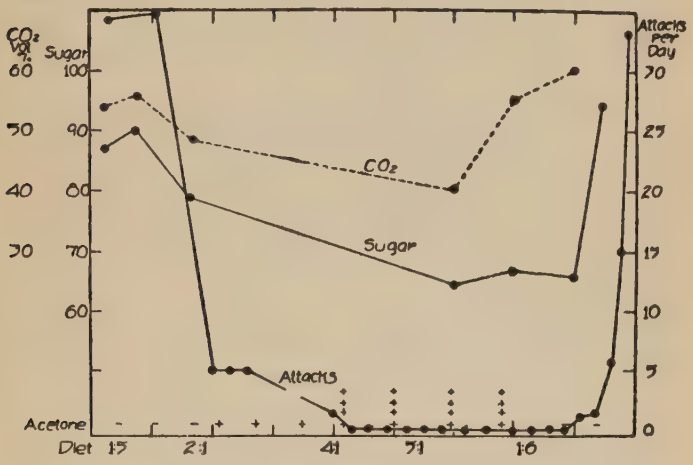


FIGURE X.

Relation of Attacks to Changes in the Blood Chemistry during Ketogenic Dieting. Talbot, Metcalf & Moriarty: Boston Med. Surg. Jour., 1927, cxcvi, 89.

A large number of reports which have appeared more recently in the American literature distinctly suggest that ketogenic therapy may prove to be highly beneficial.

Comparison of the Effectiveness of the Ketogenic Diet in Children and Adults.—On the whole the ketogenic diet has proved to be more effective in controlling epileptic seizures in children than in

adults. In general I have found that greater improvement follows establishment of the ketogenic régime before rather than after puberty. In my private practice it has been possible to control seizures more satisfactorily than in the patients of a general hospital clinic. Table XXI contains a summary of the results obtained by Peterman, Helmholz, Luther, and Talbot in their various studies of children on the ketogenic diet. Weeks, Allen, Renner, and Wishart (298) report that in six adults in an institution, treatment with diets very rich in fat content did not affect the seizures, and also did not produce marked ketosis. Lennox and Cobb (180, p. 135) say that adults do not respond to this type of therapy partly because of the "relative difficulty of maintaining acidosis in them."

TABLE XXI

COMPARISON OF RESULTS OF THE TREATMENT OF CHILDREN AND ADULTS WITH THE KETOGENIC DIET

	Number of Patients	Percentage of		Failure
		Complete Relief	Improvement	
Children				
Peterman (1926) ..	70	54	32	..
Helmholz	91	31	23	32
Luther	27	33	41	26
Talbot	20	25	45	30
Adults				
Barborka (18) ...	32	7	12	13

In order to compare the ease with which acidosis can be established and maintained in the child and the adult, I have observed four adults in addition to

the children who comprise my patients. The results show that under suitable control and with the cooperation of the patient it is equally easy to maintain marked ketosis at all ages. The degree of ketosis established in these patients was that indicated by the development of a deep Burgundy red color in the urine in the ferric-chloride test. Barborka (18) has obtained data from adults, which are less satisfactory than those obtained from younger patients (see Table XI). Probably the difference is mainly due to the additional difficulty of controlling the diet of adults with accuracy. Instances are known, however, in which adult epileptics have responded to ketogenic therapy as dramatically as any juvenile patients.

The Effect of Ketogenic Diet on Immunity and Intercurrent Illness.—A decade and a half ago a serious complication was thought to have arisen if acetone bodies appeared in the urine of children with acute illnesses. When, however, the importance of dehydration in these conditions and the relation of glucose metabolism to ketone formation came to be better understood, the conception of the significance of ketosis changed. It was, nevertheless, with considerable surprise that dietary ketosis was found apparently to act in some way as a protection against disease rather than to constitute a dreaded complication. There must be something more than mere coincidence in the fact that if a family group includes an individual with dietary ketosis, this individual usually does not develop a common cold to which all are equally exposed, while the other members of the

household do become infected. If the subject of ketosis does contract a cold it is usually less severe and of much shorter duration than that of the other members of the family. Comparable effects of ketosis have appeared in the case of two children who contracted particularly mild measles and scarlet fever respectively, and in one young patient with pneumonia whose crisis came on the third day and whose convalescence was short. Peterman reports (228) that five epileptic patients with ketosis recovered normally from severe infections such as scarlatina, pertussis, and acute respiratory affections, although their diets were not altered during the illness. From this he concludes that resistance to infection was in no way diminished by ketogenic therapy. From all the available data it seems justifiable to conclude that continuance of dietary ketosis during intercurrent illnesses is not harmful. Indeed, the evidence at hand suggests that the development of ketosis may be a protective reaction of the body during infection, and that instead of always being harmful it may at times be beneficial.

Effect of Prolonged Ketosis on Growth and Development.—Prolonged ketosis does not affect growth and development in any way so long as the fundamental needs of the body are satisfied. If all the food prescribed in the diet is eaten, weight can be gained or lost at will by increasing or diminishing the caloric intake. Accurate adjustment of the quantity of food to the bodily requirements is not always easy, however, because the type of material included in the diet is not particularly appetizing. The re-

strictions imposed by ketogenic therapy do not equally affect all constituents of food. Vitamins are automatically included in abundance, for they are present in a majority of the substances given. The proteins are carefully considered in calculation of the diet in the first place. Sufficient quantities are theoretically included, but it must be remembered that when the carbohydrate intake is reduced to a minimum, protein retention diminishes. In two of my patients, with an apparently negative protein balance for several months, growth and general development appear to have suffered in no way. This makes one wonder whether some compensatory factor may not be brought into play to counteract what appears to be daily loss of nitrogen from the body. Since the mineral salts, especially those of calcium, are lacking in nearly all ketogenic diets it is necessary to give supplementary doses in some form. Calcium lactate seems to satisfy the needs adequately, for X-ray plates of the long bones show no evidence of decalcification in patients who have been submitted to the ketogenic régime with the addition of this type of calcium medication.

Petit Mal versus Grand Mal.—A survey of the literature does not reveal any striking differences in the effect of ketogenic therapy on petit mal and on grand mal. In adults whose most common symptom is grand mal, the diet has been relatively unsatisfactory, whereas in children it has proved effective. Dehydration appears to give more benefit to adult epileptics, however, than does the diet (271), a fact which might lead one to wonder whether the ketoge-

nic diet might not be a better form of treatment for petit mal, and dehydration for grand mal. In children, however, this distinction is not valid, for the attacks of grand mal respond more quickly to ketogenic therapy. They may be converted gradually by dietetic treatment into petit mal, and then disappear; or both types of attack may be combined until complete relief is obtained.

Idiopathic versus Jacksonian or Symptomatic Epilepsy.—The effectiveness of the ketogenic diet in controlling symptomatic epilepsy has been reported in only a few cases. Helmholz states that two out of twelve patients were kept free from attacks for one or more years by this means, and that six were benefited by the treatment. I have seen definite improvement in a number of cases, but in no instance complete and permanent relief of symptoms. That there should be any improvement is surprising unless a common etiology can eventually be found for all types of epileptic symptoms.

Factors which Contribute to Therapeutic Failure.—Many factors contribute toward success or failure in the use of the ketogenic diet. The same conditions which determine the effectiveness of the treatment for diabetes determine also the effectiveness of the dietary treatment of epilepsy. Success cannot be expected when there is marked mental degeneration. Absolute coöperation of the patient, the family, and the nurse is essential. No one alone is sufficient. There must be eternal vigilance and knowledge not only of the principles of diet but of hygiene as well, for treatment may be rendered quite ineffective even

when the dietary instructions are followed with nicety if physical and mental hygiene are neglected. Excitement, fatigue, and worry go a long way toward neutralizing the good effects of the special diet. It has been striking that the successful cases in my series are those of patients who were mentally most stable and who undertook the régime without complaint, while the unsuccessful cases were comprised in large part of those who complained of its hardship, and were not well adjusted to their home and the life they were forced to live. This experience suggests that the mental hygiene of the patient is of great importance in successful treatment.

Type of Case that Can Be Treated.—Until a very much larger number of patients has been treated and studied over a long period of time, it is impossible to determine which patients should and which should not be treated. In general it may be said that treatment can be tried whenever the mentality of the patient is sufficiently good to grasp the methods of dieting, and the courage and will power are great enough to promise persistence. It is a waste of time to treat patients who take liberties with the diet, or who cannot be controlled. The accuracy with which a properly constructed diet is followed can be controlled by the urinary tests for acetone. Accumulated data will tell whether one type of case can be better treated by this type of treatment than another.

Necessary Duration of Ketosis.—The length of time for which ketosis must be maintained varies with each patient treated. Sometimes attacks even disappear for good when the ketogenic-antiketogenic

ratio of the diet is changed so slightly (from the normal of between 1: 4 and 1.5: 1) that no actual ketosis is produced; while in other cases severe ketosis must be maintained for from four to six months before it is possible gradually to shift back to a normal diet with a restricted quantity of sweets. Patients who have been treated in this way are now known to be free from attacks five years after the cessation of ketogenic treatment. When the degree of ketosis is diminished in some individuals, however, by reduction of the ketogenic-antiketogenic ratio attacks return promptly. One patient is under observation who has had varying degrees of ketosis for more than two years, the symptoms necessitating increased restriction of the diet at intervals. It can thus be seen that conditions vary greatly in different individuals, and that the chief criterion for continuing or stopping dietary therapy is the recurrence or disappearance of epileptic seizures.

Method of Return to Normal Diet.—It is unwise to change suddenly from a strong ketogenic diet to a normal one, just as it is unwise for a patient to break diet suddenly by eating candy. In both instances the result is a return of symptoms. If the time has come to return to a normal or nearly normal diet, the best procedure is either to add 10 grams of carbohydrate and omit 4½ grams of fat progressively at two-week intervals, or to change the ketogenic-antiketogenic ratio every three or four weeks in the sequence 4: 1, 3½: 1, 3: 1, 2½: 1, 2: 1, 1½: 1. The last ratio, *i.e.*, 1½: 1, should preferably be maintained for a month or two before the

patient receives a less restricted, normal assortment of foods.

The Use of the Ketogenic Diet in a Relapse.—If, after a period of freedom or comparative freedom from dietary restrictions, epileptic symptoms reappear, the ketogenic-antiketogenic ratio may be increased very rapidly, so that at the end of a week or two it has reached the maximum ever previously used by the patient. The speed with which it is desirable to reach this maximum point depends upon the ratio in use when the relapse began. The more nearly normal the diet has been, the longer should be the time taken to work back to the high ratio, but even when the food intake has been comparatively unrestricted two weeks is usually the greatest length of time required.

CHAPTER XVI

The Practical Use of the Ketogenic Diet

Although scientific investigation has not yet progressed far enough to indicate clearly how and why the ketogenic diet is beneficial, for clinical purposes it may be assumed that its purpose is to cause ketosis.

Methods of Producing Ketosis.—Dietary ketosis results when the food contains more molecules of fatty acids than of glucose (high-fat low-carbohydrate diet). The degree of ketosis depends on the ratio of these two constituents and can therefore be controlled at will. For the sake of simplicity the ratio is expressed in grams of food rather than in less obvious units. Since in practice it is never wise to shift suddenly from one type of diet to another, ketosis should be produced gradually by slight changes at given intervals in the ratio between the ketogenic and the non-ketogenic elements. There is some variation in the average composition of the so-called normal diet, but on the whole it may be said to contain about one part of ketogenic material for every four to six parts of non-ketogenic material. If this is the case, ketogenic therapy may be begun by changing the ratio to 1½: 1. After this marked reduction in the carbohydrate intake has been maintained for two or three weeks in order to permit ad-

justment of the digestion and metabolism to the new conditions, further changes may be made at intervals of one week to the ratios 2: 1, 2½: 1, 3: 1, 3½: 1, and if necessary 4 or more to 1. It should be kept in mind, throughout these changes, however, that in no case is the daily carbohydrate content of the diet to be reduced below 8 grams.

Tests for Ketosis.—Ketosis develops soon after the beginning of treatment if the diet is accurately planned and weighed. Acetone in the breath is sometimes demonstrable by the Higgins' test (117) when the food ratio is 1½: 1. The urinary reaction for acetone is not positive in the sodium nitroprusside test until the ratio is 2:1, in the ferric-chloride test until it is 2½: 1. These reactions are found regularly if the diet is accurately planned and taken. The figures are lower than those of Helmholz, because of the different method of calculating the ketogenic-antiketogenic ratio. Tests for ketosis fall into two separate categories: the first, that of the simple tests which can be performed without elaborate apparatus and long training; the second, that of tests which require laboratory equipment and considerable technical skill. The three tests mentioned above fall into the first group. The test to determine the carbon dioxid combining power of the blood, on the other hand, and various others are not practical unless laboratory privileges are readily available.

Higgins' Test for Acetone in the Breath (117).

This test consists in collecting the breath in a 1000 c.c. capacity football bladder. The patient fills the bladder

to capacity with breath from his lungs, and the contents is then blown through 25 c.c. of Scott-Wilson Acetone Reagent in about 30 seconds. If acetone is present a white cloud is formed. This is compared with the cloud produced in other tubes of Scott-Wilson Reagent by known amounts of a standard solution of acetone. If great accuracy is desired in determination of the concentration of acetone this may be done by means of a nephelometer.

Scott-Wilson Acetone Reagent (253).

Mercuric cyanide	10 grams
Sodium hydroxide	.180 grams
Water	1000 c.c.

The solution is shaken in a flask and 400 c.c. of 0.7268 per cent of silver nitrate is added. This reagent will keep indefinitely, the clear fluid being decanted from the precipitate which tends to form.

Urinary Tests to Demonstrate the Degree of Ketosis.

The Ferric-Chloride Test.—Into an ordinary test-tube pour about an inch of urine. With this mix an equal quantity of ferric chloride. If the color becomes Burgundy red, acetone, a product of ketosis, is present. If the color remains unchanged, sufficient ketosis has not developed.

The Sodium Nitroprusside Test.—Place about 10 sodium nitroprusside crystals and an inch of urine in a test-tube and shake until the crystals are dissolved. Then add 2 or 3 drops of glacial acetic acid and again shake. Next, pour 28 per cent ammonium hydroxide into the test-tube so that it forms a layer on top of the original solution and does not mix with it. If acetone is present in the urine a reddish purple ring forms at the junction of the two solutions. The deeper the color, the greater the proportion of acetone in the urine.

Total Caloric Needs.—Estimation of the caloric needs per kilogram of body weight has proved unsatisfactory in children, because one purpose of accurate dieting is so to adjust the food intake that the child will attain the weight ideal for his height. If this method of calculation is used for two children of the same height and age, one obese and the other thin, the obese child will receive many more calories in the food than the thin child, and existing physical deviations will be emphasized. If, on the other hand, both are given the number of calories required by an average individual of their height and age, the obese child will lose some weight and the thin child will be given an opportunity to gain. Since one purpose of the treatment of epilepsy is to get the patient into the best general health possible, such factors play an important rôle in calculation of the food intake. The average weight of an individual of any height and age is shown in Tables VII, VIII, and IX.

In addition to the height and age of the patient, the habitual degree of activity must be considered in dietary calculations. A very quiet person needs only slightly more than the theoretical minimum requirement of food, while a very active one needs nearly the maximum allowance. Figures for the minimal and maximal limits for all ages up to fifteen years are given in Table X. The minimal needs are determined by adding 50 per cent to the basal metabolism of average normal children of the given age and height. The figures to be thus used as a starting point may also be found in Table X. The maximal basal requirements are less readily determined, as can be

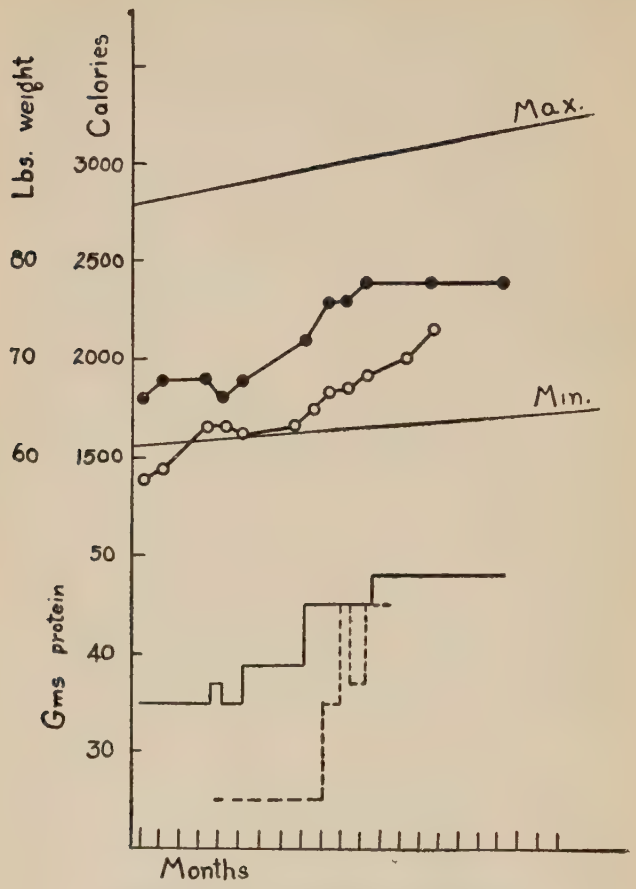


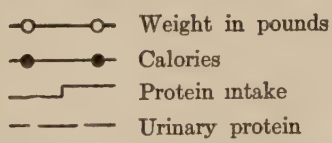
FIGURE XI. (See legend on page 211.)

seen by Holt's review of the literature on this subject (122, 123) and by various cases from my clinic. Over-eating is just as bad if not worse for the health of epileptic children than is under-eating. In practice it is generally wise to give at first a little more than the minimal caloric requirement indicated in Table X, and to weigh the child once a week to determine whether or not this is sufficient. The caloric allowance can then be increased or decreased according to the changes which take place, and the child can report as to whether he is constantly hungry or finds it difficult to eat all the food provided. Figures III and XI illustrate the close relationship between weight and quantity of food taken. Throughout treatment the diet and hygiene should be so arranged that normal growth continues, the body weight becomes what it should be for the height, the muscles and bones develop, the tone im-

FIGURE XI.

Relation between Weight and Caloric Intake.

B. S. is a girl of 9 years whose height was 54¼ inches at the beginning of dietary treatment, and 55¾ inches nine months later. She was observed for two years and four months. At first while receiving 1650 calories, approximately the minimal requirement, she lost weight rapidly. When the caloric intake was raised to 2300, her weight increased rapidly. This gain continued even when the quantity of food was reduced to approximately 2000 calories.



The minimum and maximum caloric requirements are shown by the lines marked Min. and Max.

proves, and the general health becomes as nearly perfect as possible. In studying the relation between the weight and diet it must not be forgotten that other factors such as the inorganic-salt content and the acid-base balance of the food are important. (See pages 240, 241.) The tendency for acid foods to increase and for alkaline foods to decrease water excretion should also be kept in mind.

The most commonly encountered causes of an increase in weight are over-eating, ingestion of a large amount of carbohydrate, inclusion of too much common salt in the food, and hypothyroidism. A false temporary increase results from retention of urine and feces.

Loss in weight usually results from under-feeding, fasting, fever, vomiting, and diarrhea,—conditions which are often caused by worry or bad food habits. Relative underfeeding may follow increase in the amount of exercise taken if the diet is not correspondingly enlarged. Temporary losses are often due to sweating during exercise, or hot weather, to catharsis, and to diuresis. Thyroid therapy and restriction to a low-carbohydrate or to a low-salt (NaCl) diet are also at times responsible for loss of body weight.

Protein Requirements.—Since about one-half of protein is antiketogenic in its action, it is desirable during ketogenic therapy to reduce the quantity of protein in the food to the minimum compatible with good health in order to permit inclusion in the diet of a small amount of carbohydrate. Without any carbohydrate at all, food is extremely unpalatable. Dur-

ing childhood the minimal protein needs are fulfilled by 1 gram of protein per kilo of body weight, while during adult life 0.6 gram suffices. When the amount of carbohydrate in the food is so reduced that profound ketosis exists, the protein requirements increase usually to 1.25 grams per kilo in the child, and to 0.8-1.0 gram in the adult. These figures do not apply to all individuals under all conditions, but can be used as a general working basis for the calculation of diets. The adequacy of the quantities of protein given each patient should be determined from time to time by examination of the total quantity of urine passed in a period of seventy-two hours. The amount excreted in the feces can be disregarded in the dietary calculations, for it is small at most, and decreases as the proportion of fat in the food increases. It is probable that if the amount of nitrogen in the food exceeds the quantity in the urine by two grams, there is no loss of nitrogen (protein) from the body.

In fifteen children who were undergoing ketogenic therapy at the Massachusetts General Hospital, Dr. Metcalf and Miss Moriarty studied the protein balance. In only six out of ninety instances was there evidence of a negative balance when the intake was 1 gram per kilo of body weight. Since the output of nitrogen exceeded the intake only when the dietary ratio was 3: 1 or 4: 1, these investigators concluded that a greater allowance of protein was necessary when the ratio was high. An additional ¼ gram appeared to satisfy the extra requirement.

Clinical Method for Estimating the Ketogenic-Antiketogenic Ratios and Planning Changes in the Diet.—The prime requisite for the clinical management of ketogenic diets is a knowledge of the amount of fat, carbohydrate, and protein in the various foods commonly used. Table XXII contains an incomplete list, but will be found helpful, nevertheless, in arranging suitable menus for patients undergoing ketogenic therapy. More inclusive lists are mentioned by Joslin (150).

There are three separate methods of calculating the ketogenic-antiketogenic ratio after the relative proportions of the three foodstuffs in the various articles of diet are known. Metcalf and Moriarty (278) at the Massachusetts General Hospital employ the gram ketogenic-antiketogenic ratio and find it very practical and satisfactory. Their formula is:

$$\text{Total Calories} = \text{Ratio} \times 9(C + P) + 4C + 4P$$

Woodyatt (303) uses the formulæ:

$$\text{Ketogenic ratio} = \frac{\text{grams Fatty Acid}}{\text{grams Glucose}}$$

$$\text{Carbohydrate} = \frac{0.46\ (\text{gms. Protein}) + 0.90\ (\text{gms. Fat})}{0.58\ (\text{gms. Protein}) + 0.10\ (\text{gms. Fat})}$$

And Shaffer determines the ratio in molecular terms (255, 257, 259) as follows:

$$\text{Ketogenic Ratio} = \frac{\text{mols. ketogenic equivalents (as Aceto-acetic acid)}}{\text{mols. antiketogenic equivalents (glucose)}}$$

$$= \frac{2.4 \times (\text{gms. urinary Protein}) + 3.43 \times (\text{gms. Fat burned})}{5.56\ (\text{gms. Carbohydrate burned}) + 3.2 \times (\text{gms. Urinary Protein}) + 0.57\ (\text{gms. Fat burned})}$$

TABLE XXII

COMPOSITION OF NORMAL FOODS *

MEAT PRODUCTS

Name and Description of Food	Water *per cent*	Protein *per cent*	Fat *per cent*	Carbohydrate *per cent*	Calories *per 100 grams*
Beef, fresh:					
Flank, edible portion	59.3	19.6	21.1	...	268
Loin, edible portion	61.3	19.0	19.1	...	247
Ribs, edible portion	57.0	17.8	24.6	...	293
Liver, as purchased	65.6	20.2	3.1	2.5	119
Sweetbreads, as purchased	70.9	16.8	12.1	...	176
Tongue, edible portion	70.8	18.9	9.2	...	158
Beef, corned and pickled:					
Corned beef, edible portion	53.6	15.6	26.2	...	298
Tripe	86.5	11.7	1.2	Trace	58
Veal, fresh:					
Flank, edible portion	66.9	20.1	12.7	...	195
Leg, edible portion	71.7	20.7	6.7	...	143
Cutlets, edible portion	70.7	20.3	7.7	...	151
Loin, edible portion	69.5	19.9	10.0	...	170
Liver, as purchased	73.0	19.0	5.3	...	124
Lamb, cooked:					
Chops, broiled, edible portion	47.6	21.7	29.9	...	356
Leg, roast	67.1	19.7	12.7	...	193
Mutton, cooked:					
Leg, roast, edible portion	50.9	25.0	22.6	...	303
Pork, fresh:					
Ham, medium fat, edible portion	53.9	15.3	28.9	...	321
Loin, chops, medium fat edible portion	52.0	16.6	20.1	...	337
Pork, pickled, salted or smoked:					
Pig's feet, pickled, edible portion	68.2	16.3	14.8	...	198
Salt pork, clear fat	7.9	1.9	86.2	...	783
Bacon, smoked, edible portion	20.2	10.5	64.8	...	625
Sausage:					
Bologna, edible portion	60.0	18.7	17.6	0.6	236
Frankfort	57.2	19.6	18.6	1.1	250
Deerfoot Farm, cooked (analysis furnished by manufacturer)	...	19.9	54.2	.8	569

POULTRY

Poultry, fresh:					
Chicken, broilers, edible portion	74.8	21.5	2.5	...	109
liver, as purchased	69.3	22.4	4.2	2.4	137
Fowls, edible portion	63.7	19.3	16.3	...	224
Turkey, edible portion	55.5	21.1	22.9	...	291

FISH PRODUCTS

Fish, fresh:					
Bluefish, edible portion	78.5	19.4	1.2	...	88
Butterfish, edible portion	70.0	18.0	11.0	...	171
Cod, edible portion	82.5	16.7	0.3	...	70
Haddock, edible portion	81.7	17.2	0.3	...	72
Halibut, edible portion	75.4	18.6	5.2	...	121
Mackerel, edible portion	73.4	18.7	7.1	...	139
Salmon, edible portion	64.6	22.0	12.8	...	203
Shad, edible portion	70.6	18.8	9.5	...	161

TABLE XXII—*Continued*

FISH PRODUCTS—*Continued*

Name and Description of Food	Water *per cent*	Protein *per cent*	Fat *per cent*	Carbohydrate *per cent*	Calories *per 100 grams*
Fish, fresh:—Continued					
Shad roe, as purchased	71.2	20.9	3.8	2.6	128
Smelt, edible portion	79.2	17.6	1.8	...	87
Trout, brook, edible portion	77.8	19.2	2.1	...	96
Trout, lake, edible portion	70.8	17.8	10.3	...	164
Fish, preserved or canned:					
Cod, salt, boneless, as purchased	54.8	27.7	0.3	...	114
Shellfish, etc., fresh:					
Clams, long, in shell, edible portion	85.8	8.6	1.0	2.0	51
Crabs, hard shell, whole edible portion	77.1	16.6	2.0	1.2	89
Lobster, edible portion	79.2	16.4	1.8	0.4	83
Oysters, in shell, edible portion	86.9	6.2	1.2	3.7	50
Scallops, as purchased	80.3	14.8	0.1	3.4	74
GELATIN					
Gelatin	13.6	84.2	0.1	...	338
EGGS					
Eggs, edible portion, cooked:					
Hen, boiled	73.2	13.2	12.0	...	161
Whites	86.2	12.3	0.2	...	51
Yolks	49.5	15.7	33.3	...	363
DAIRY PRODUCTS, ETC.					
Milk:					
Milk, whole	87.	3.3	4.0	4.8	68
Buttermilk	91.	3.6	0.5	4.1	35
Cream, heavy (approximately 40 per cent)	...	2.1	41.0	1.5	383
light (approximately 20 per cent)	...	2.8	22.0	2.7	220
Cheese:					
American, pale	31.6	28.8	35.9	0.3	440
red	28.6	29.6	38.3	...	463
Camembert	...	21.0	21.7	...	279
Cottage	72.0	20.9	1.0	4.3	110
Edam	...	24.1	30.3	4.6	388
Full cream	...	25.4	30.3	2.0	382
Neufchatel	50.0	18.7	27.4	1.5	327
Roquefort	39.3	22.6	29.5	1.8	363
Swiss	31.4	27.6	34.9	1.3	430
Ice cream, typical	...	3.8	12.6	19.6	207
FATS AND OILS					
Fats and oils:					
Butter, average	11.	1.5	84.6	...	767
Salad oils and cooking fat	...	Trace	99.7	None	897

TABLE XXII—*Continued*

SOUPS AND BROTHS

Name and Description of Food	Water *per cent*	Protein *per cent*	Fat *per cent*	Carbohydrate *per cent*	Calories *per 100 grams*
Soups, broths, etc., canned:					
Bouillon, beef	96.6	2.2	0.1	0.2	11
Consommé	96.0	1.4	0.1	0.4	8
Julienne	95.9	2.7	...	0.5	13
Pea soup	86.9	3.6	0.7	7.6	51
Tomato soup	90.0	1.8	1.1	5.6	40
Vegetable	95.7	2.9	...	0.5	14
Bouillon cubes:					
As purchased, average analysis	...	11.4	1.8	5.8	85

CEREAL PRODUCTS, ETC.

Bread, soft:					
Bread, corn (Johnnycake)	38.9	7.9	4.7	46.3	259
Graham	35.7	8.9	1.8	51.0	256
rye	35.7	9.0	0.6	52.7	252
wheat, average of many analyses	35.3	9.2	1.3	52.6	259
wheat, whole	38.4	9.7	0.9	48.5	241
Bread, hard, and crackers:					
Bread, white, toasted	24.0	11.5	1.6	61.2	305
Zwieback	5.8	9.8	9.9	73.5	422
Crackers, Boston (split)	7.5	11.0	8.5	70.3	402
Pastry, etc.:					
Doughnuts	18.3	6.7	21.0	52.4	425
Fig Bars	17.9	4.6	6.6	68.1	350
Ginger snaps	6.3	6.5	8.6	75.3	405
Lady fingers	15.0	8.8	5.0	70.4	362
Macaroons	12.3	6.5	15.2	64.1	419
Pie, apple	42.5	3.1	9.8	42.8	272
custard	62.4	4.2	6.3	26.1	178
lemon	47.4	3.6	10.1	37.4	255
squash	64.2	4.4	8.4	21.7	180
Pudding, Indian meal	60.7	5.5	4.8	27.5	175
rice custard	59.4	4.0	4.6	31.4	183
tapioca	64.5	3.3	3.2	28.2	155
Breakfast foods:					
Corn (maize) preparations:					
flakes, crisps, puffs, etc., average of 8 brands	...	7.4	0.3	79.2	349
Oat preparations:					
rolled oats, crushed oats, oat flakes, average of 12 analyses	...	15.4	6.8	64.1	379
oatmeal, boiled (85 per cent water)	84.5	2.8	0.5	11.5	62
oatmeal, gruel (92 per cent water)	91.6	1.2	0.4	6.3	34
oatmeal water (96 per cent water)	96.0	0.7	0.1	2.9	15
Rice preparations:					
rice flakes, puffs, etc., average of 7 analyses	...	8.2	0.2	79.8	354
rice, boiled (73 per cent water)	72.5	2.8	0.1	24.4	110
Wheat preparations:					
cracked and crushed	10.1	11.1	1.7	73.8	355
farina	10.9	11.0	1.4	75.9	360
shredded	8.1	10.5	1.4	76.2	359

TABLE XXII—*Continued*

VEGETABLES

Name and Description of Food	Water *per cent*	Protein *per cent*	Fat *per cent*	Carbohydrate *per cent*	Calories *per 100 grams*
Vegetables, fresh (unless otherwise stated):					
Artichokes	79.5	2.6	0.2	15.9	76
Jerusalem	...	2.9	0.1	16.4	78
cooked	...	2.4	0.1	16.5	77
Asparagus	94.0	1.8	0.2	2.4	19
Beans, butter	58.9	9.4	0.6	29.1	159
lima	68.5	7.1	0.7	20.3	116
string (carbohydrate range 3.9 to 10 per cent)	89.2	2.3	0.3	5.5	34
string, cooked	95.3	0.8	1.1	1.9	21
Beets, (carbohydrate range, 6 to 10 per cent)	87.5	1.6	0.1	8.8	43
cooked	88.6	2.3	0.1	7.4	40
Brussels sprouts	93.7	1.5	0.1	3.4	21
Cabbage (carbohydrate range, 3 to 6.5 per cent)	91.5	1.6	0.3	4.5	27
Carrots (carbohydrate range, 5.9 to 11.5 per cent)	88.2	1.1	0.4	8.2	41
Cauliflower	92.3	1.8	0.5	3.7	27
Celery	94.5	1.1	0.1	3.3	19
Chard (Swiss)	...	3.2	0.6	5.0	38
Corn	75.4	3.1	1.1	19.2	99
Cucumbers	95.4	0.8	0.2	2.3	14
Egg plant	92.9	1.2	0.3	4.3	25
Endive	...	1.0	None	2.6	14
Finocchio	...	1.5	0.1	1.6	13
Greens, beet, cooked	89.5	2.2	3.4	3.2	52
dandelion, as purchased	...	2.7	0.8	6.3	43
Kale	...	3.0	0.4	2.1	24
Lettuce	94.7	1.2	0.3	2.2	16
Mushrooms	88.1	3.5	0.4	6.0	42
Onions (carbohydrate range, 4 to 14 per cent)	87.6	1.6	0.3	9.0	45
cooked	91.2	1.2	1.8	4.9	41
Parsnips (carbohydrate range, 6-14 per cent)	83.0	1.6	0.5	11.0	55
Peas, green, cooked	73.8	6.7	3.4	14.6	116
Peppers, Neapolitan	...	1.1	0.3	5.7	30
Potatoes, sweet (carbohydrate range, 16.5-44.5 per cent)	69.0	1.8	0.7	26.1	118
Potatoes	78.3	2.2	0.1	18.0	82
Pumpkins (carbohydrate range, 3-14 per cent)	93.1	1.0	0.1	6.0	29
Radishes (carbohydrate range, 2.7-7.5 per cent)	91.8	1.3	0.1	5.1	27
Rhubarb	94.4	0.6	0.7	2.5	19
Sauerkraut	88.8	1.7	0.5	3.0	23
Spinach	92.3	2.1	0.3	2.3	20
Squash	88.3	1.4	0.5	8.2	43
Tomatoes	94.3	0.9	0.4	3.3	20
Turnips (carbohydrate range, 2.3-18 per cent)	89.6	1.3	0.2	6.8	34
Watercress	...	0.7	0.5	3.7	22
Yams	...	1.6	0.2	23.6	103

TABLE XXII—*Continued*

VEGETABLES—*Continued*

Name and Description of Food	Water *per cent*	Protein *per cent*	Fat *per cent*	Carbohydrate *per cent*	Calories *per 100 grams*
Vegetables, canned:					
Asparagus (carbohydrate range, 1.6-3.3 per cent)	94.4	1.5	0.1	2.3	16
Beans, baked	68.9	6.9	2.5	17.1	119
string (carbohydrate range, 1.5-4.5 per cent)	93.7	1.1	0.1	3.3	19
Peas, (carbohydrate range 4.3-17.2 per cent)	85.3	3.6	0.2	8.6	51
Tomatoes (carbohydrate range, 1-4.5 per cent)	94.0	1.2	0.2	3.5	21

PICKLES, CONDIMENTS, ETC.

Pickles, condiments, etc.:					
Catsup, tomato (carbohydrate range, 3-26 per cent)	...	1.8	0.2	10.0	49
Chili sauce (carbohydrate range, 14-28 per cent)	...	...	...	20.0	...
Olives, green, edible portion	..	2.1	12.9	1.8	132
Pickles, cucumber	92.9	0.5	0.3	2.7	16
Vinegar, cider (carbohydrate range, 0.3-1.5 per cent)	...	None	None	0.3	1

FRUITS, BERRIES, ETC.

(Analyses are of edible portion)

Fruits, berries, etc., fresh:					
Apples (carbohydrate range, 9-21 per cent)	84.6	0.4	0.5	13.0	58
Apricots	85.0	1.1	...	12.0	...
Avocados (alligator pears)	...	1.1	13.7	7.1	156
Bananas	75.3	1.3	0.2	20.0	88
Blackberries	86.3	1.3	1.0	8.4	48
Cherries	80.9	1.0	0.8	16.5	77
Cranberries	88.9	0.4	0.6	8.4	41
Currants	85.0	1.5	...	12.8	...
Figs	79.1	1.5	...	18.8	...
Gooseberries	...	0.4	...	12.0	...
Grapes	77.4	1.3	1.6	14.9	79
Grape juice (carbohydrate range, 11-20 per cent)	...	...	...	15.0	...
Grapefruit	...	...	...	7.2	...
Huckleberries	81.9	0.6	0.6	16.6	74
Lemons	89.3	1.0	0.7	7.4	40
Oranges	86.9	0.8	0.2	11.6	51
Peaches	...	0.5	0.2	9.0	40
Pears	84.4	0.6	0.5	11.4	53
Pineapple	89.3	0.4	0.3	12.0	52
Plums	78.4	1.0	...	17.0	...
Prunes	79.6	0.8	...	19.0	...
Quince	...	0.3	0.1	13.2	55
Raspberries, black	84.1	1.7	1.0	10.0	56
red	85.8	1.0	...	9.7	...
Strawberries	90.4	1.0	0.6	6.0	33
Watermelons	92.0	0.3	0.1	7.0	30

TABLE XXII—*Continued*

FRUITS, BERRIES, ETC.—*Continued*

Name and Description of Food	Water *per cent*	Protein *per cent*	Fat *per cent*	Carbohydrate *per cent*	Calories *per 100 grams*
Fruits, berries, etc., canned; jellies and preserves:					
Apricots	81.4	0.9	...	17.3	...
Marmalade, orange	14.5	0.6	0.1	84.5	341
Peaches	88.1	0.7	0.1	10.8	47
Pears	81.1	0.3	0.3	18.0	76
Pineapple	61.8	0.4	0.7	36.4	154

NUTS

(Analyses are of edible portion)

Nuts:					
Almond	4.8	21.0	54.9	15.3	639
Brazil nuts	5.3	17.0	66.8	7.0	697
Butternuts	4.4	27.9	61.2	3.5	676
Cashew nuts	...	9.7	47.2	17.0	532
Chestnuts	45.0	6.2	5.4	40.3	235
Cocoanuts	14.1	5.7	50.6	27.9	590
Cocoanut milk	92.7	0.4	1.5	4.6	34
Peanuts	9.2	25.8	38.6	21.9	538
Peanut butter	2.1	29.3	46.5	17.1	604
Pecans	2.7	9.6	70.5	15.3	734
Pistachios	4.2	22.3	54.0	16.3	640
Walnuts, California	2.5	18.4	64.4	11.6	700

BEVERAGES

Tea (0.5 oz. to 1 pt. water)	...	...	...	0.6	...
Coffee (1 oz. to 1 pt. water)	...	...	...	0.7	...
Cocoa (0.5 oz. to 1 pt. water)	...	...	...	1.1	...
(0.5 oz. to 1 pt. milk)	...	...	...	6.0	...
Carbonated drinks (bottled soda, sarsaparilla, birch beer, root beer, ginger ale)	...	...	...	8.0	...

* The figures for the water content were taken from Atwater, W. O., and Bryant, A. P.: "The Chemical Composition of American Food Materials," *Bull. No. 28 (Revised Edition), of the U. S. Department of Agriculture,* 1899. All the other figures are from Table 27 of Dr. Elliott P. Joslin's *Diabetic Manual,* Revised Edition, 1924.

Since the results of these three methods of calculation are not identical it is essential to decide upon the one to be used and to employ this consistently. Table XXIII, which was prepared by Metcalf and Moriarty, shows the comparative ratios obtained by the three methods. The calculation in use at the

Mayo Clinic in Rochester, Minnesota (206) is very similar in principle to that of Metcalf and Moriarty, but differs from it in detail.

TABLE XXIII

COMPARATIVE RESULTS OF CALCULATING THE KETOGENIC-ANTIKETOGENIC RATIO OF THE DIET BY THE METCALF AND MORIARTY, THE WOODYATT, AND THE SHAFFER FORMULÆ. THE FIGURES ARE COMPILED BY METCALF AND MORIARTY (278).

	M. & M. grams F: P + C	Woodyatt grams Fatty Acid: Glucose	Shaffer mols. K: AK
C = 66 P = 40 F = 159	1.5: 1	1.53: 1	1.02: 1
C = 44 P = 40 F = 168	2: 1	2.1 : 1	1.4 : 1
C = 20 P = 40 F = 180	3:1	2.96: 1	1.97: 1
C = 6 P = 40 F = 184	4: 1	3.9 : 1	2.6 : 1

Illustrative Estimation of a Diet with a 2 1/2: 1 Ratio for a Child Nine Years Old.—Suppose the patient to be a quiet girl 9 years old and 51 inches tall who weighs 61½ pounds (28 kilograms). The first step in determining her caloric needs is to compare her height and weight with those of other girls of the same age. By consulting Table VII it will be found that she is of the normal height for her age and that she has the average weight for her height. Her caloric requirements are therefore those of the average girl of 9 years. Since the minimum needs are 1375 and the maximum 2300 calories (See Table X) the therapeutic diet should contain 1600 calories, or about 200 more than the minimal allowance. Had the patient been active, 1800 calories would have been a better number for the initial quota. After this diet has begun, weekly weighing will indicate whether or not sufficient food has been allowed to compensate for

activity. In this case, however, it can be assumed that 1600 calories is adequate provision, because the child has presumably already been watched while receiving suitable diets with the ratios 1½: 1 and 2: 1. The problem here to be considered is, then, not so much determination of the caloric content itself as it is calculation of the relative amounts of the three food constituents (fat, carbohydrate, and protein) which will produce a ketogenic-antiketogenic ratio of 2½: 1. As has already been pointed out, the quantity of protein to be given is determined by the body weight of the child. In this instance the minimal allowance of 28 grams (1 kilogram per kilogram of body weight) is increased by 3 grams to compensate for the extra loss of protein which accompanies ketosis and a decrease in the carbohydrate intake. This means that 31 (the number of grams of protein) times 4 (the number of calories contained in 1 gram of protein) or 124 calories out of the total 1600 will be derived from protein. The rest must be obtained from fat and carbohydrate, for the most part from fat.

Using the calculation of Metcalf and Moriarty we employ first the formula

(1) Ratio = F (fat): C (carbohydrate) + P (Protein)

which by substitution becomes

(2) $2\frac{1}{2}:1 = F:C + 31$ or
(3) $1F = 2\frac{1}{2}(C + 31)$

If now it is agreed to let F, C, and P represent the number of grams of fat, carbohydrate, and protein respectively which are needed in the diet, and if it is

known that 1 gram of fat provides 9 calories, 1 gram of protein 4, and 1 gram of carbohydrate 4, we can use the formula

(4) 1600 calories $= 9F + 4C + 4P$

When the known values for fat (Formula 3) and protein are inserted in this by substitution we have

(5) $1600 = 9(2.5(C + 31)) + 4C + 124$

Solution of this equation gives values of 151 grams of fat, 29 grams of carbohydrate, and 31 grams of protein as the allowances for this diet.

Fortunately in actual utilization of the diets it is not necessary to go through all this mathematical procedure, because Dr. Eliot Luther and Dr. Walter Bartlett of the Massachusetts General Hospital have calculated all the results necessary and compiled them in a table (Table XXIV). To use this, decide upon the total caloric requirement of the patient, then look in the appropriate columns for the number of grams of fat and carbohydrate plus protein which are needed to give the various ketogenic-antiketogenic ratios. Since the protein requirements are known (1 gram per kilo of body weight), the number of grams of carbohydrate to be included is found by subtracting the number of grams of protein from the sum of the grams of carbohydrate and protein as given in the table.

Report of a Case which Illustrates the Effectiveness of a Ketogenic Diet and the Physical Changes which Accompany this Type of Therapy.

The patient, E. S., a girl 54⅜ inches tall, was 10 years and 3 months old at the time of first consultation in the

DIET CALCULATION TABLE.

GRAM RATIOS

	1 : 1		1.5 : 1		2 : 1		2.5 : 1		3 : 1		3.5 : 1		4 : 1	
CALS.	F	C·P	F	C·P	F	C·P	F	C·P	F	C·P	F	C·P	F	C·P
1000	77	77	86	57	91	45	94	38	97	32	99	28	100	25
1100	85	85	94	63	100	50	104	41	106	36	108	31	110	27
1200	92	92	103	69	109	55	113	45	116	39	118	34	120	30
1300	100	100	111	74	118	59	123	49	126	42	128	37	130	32
1400	108	108	120	80	128	64	132	53	135	45	138	40	140	35
1500	115	115	129	86	136	68	141	57	144	48	148	42	150	38
1600	123	123	137	91	146	73	151	60	156	52	157	45	160	40
1700	131	131	146	97	154	77	160	64	165	55	168	48	170	43
1800	138	138	155	103	164	82	170	68	174	58	177	51	180	45
1900	146	146	162	108	172	86	180	72	183	61	187	54	190	48
2000	154	154	171	114	182	91	190	76	195	65	197	56	200	50
2100	162	162	180	120	191	95	198	79	203	68	207	59	210	52
2200	169	169	189	126	200	100	207	83	213	71	217	62	220	55
2300	177	177	197	131	209	105	217	87	222	74	227	65	230	57
2400	185	185	206	137	218	109	226	91	232	77	236	68	240	60
2500	192	192	214	143	228	114	236	95	242	81	246	70	250	62
2600	200	200	222	148	236	118	245	99	249	83	255	73	260	65
2700	208	208	231	154	244	122	252	101	261	87	266	76	268	67
2800	215	215	240	160	254	127	262	105	270	90	273	78	280	70
2900	223	223	247	165	262	131	272	109	279	93	283	81	288	72
3000	231	231	253	170	274	137	282	113	291	97	294	84	300	75
3100	238	238	265	177	280	140	292	117	300	100	304	87	318	77
3200	246	246	273	182	290	145	300	120	309	103	314	90	320	80
3300	254	254	282	188	300	150	310	124	318	106	322	92	328	82
3400	261	261	291	194	308	154	320	128	327	109	332	95	340	85
3500	269	269	300	200	318	159	330	132	336	112	343	98	348	87

TABLE XXIV.

Data of Luther, E. H., and Bartlett, W. M.: Massachusetts General Hospital, Boston, Mass. Not previously published.

fall of 1927. She had no family history suggesting epilepsy. Her first symptoms, which were reported to have appeared about four months before she was examined, consisted of fainting spells which began without warning and also definite attacks of twitching which increased gradually in frequency until at the time the history was taken they occurred about once in six days. A thorough physical examination revealed nothing abnormal, and no anomalies could be found in x-ray photographs of the gastrointestinal tract and skull.

The patient was not allowed to go to school, but studied music and was tutored at home. Dietary therapy was begun soon after examination when the body weight was 76¼ pounds (34.7 kilograms),—the first diet used having a ketogenic-antiketogenic ratio of 1½:1. The caloric allowance of 1800 was obtained from 158 grams of fat, 70 grams of carbohydrate, and 35 grams of protein. The appetite soon became so poor that it was difficult to eat all the breakfast provided, and olive oil was then given instead of part of the cream originally included in the menus. After a week the weight had fallen to 75½ pounds (34.3 kilograms) and E. S. was a little more hungry. The ratio was then changed to 2:1, and an additional 100 calories were provided, the total 1900 calories being derived from 172 grams of fat, 51 grams of carbohydrate, and 35 grams of protein. The urine reacted positively in the sodium nitroprusside test for acetone. Attacks still continued and the parents felt that the child must not be left alone for a minute. She was given regulated exercises and definite periods were reserved for walking and resting. Ten days later the weight was 75 pounds (34 kilograms) and E. S. was still hungry. The food allowance was again increased to 190 grams of fat, 36 grams of carbohydrate, and 40 grams of protein which provided 2000 calories, with a ratio of 2½:1. The total urinary nitrogen excretion for a twenty-four hour period indicated that the nitrogen balance was positive at this time although the weight was decreasing. After

an interval of ten days the dietary ratio was changed to 3:1 without any alteration in the total caloric allowance. This meant that the food consisted of 195 grams of fat, 25 grams of carbohydrate, and 40 grams of protein daily. While on this diet the sodium nitroprusside test for urinary acetone was strongly positive.

At this time E. S. was sent to the country where she remained for two months with her nurse. She had no attacks at all during this time and no difficulty in taking the food prescribed except once when she did not want her supper because of pain in the stomach. The local doctor examined the child and found no evidence of appendicitis, but thought that much more gas than normal was present in the large intestine. This condition is not unusual in children restricted to a high-fat diet. As a remedy until the appetite returned the total quantity of food was diminished without changing the ketogenic ratio.

At the end of the two months a party, at home, was given for E. S. and with another child she spent the day playing actively outdoors and getting quite excited. An attack resulted, which, so far as could be determined, was not due to any slip in dieting but to the unusual excitement of playing with her friend. At this time it was thought best to support the abdomen, which was sagging, by means of anterior and posterior pads. No alteration was made in the diet. Throughout the spring E. S. continued to look progressively stronger and healthier and was quite free from symptoms until a slight attack occurred about two months after the one which followed her party. As a result of this the dietary ratio was increased to 3½:1. At the same time, because the child was hungry and had not gained in weight, 100 calories were added to the total allowance. The daily quantities of food given were then 207 grams of fat, 16 grams of carbohydrate, and 43 grams of protein. In the next two months E. S. grew an inch, was quite free from attacks, and had a good appetite. An addition of 100

calories was therefore given without a change in the dietary ratio.

Four months later, in the autumn, it was found that there had been a gain in weight and the allowance was again increased, this time to 2400 calories, derived from 236 grams of fat, 22 grams of carbohydrate, and 46 grams of protein. When this was done E. S. had been free from attacks for six months and was in magnificent physical condition. She returned to school without untoward results. The strength of the diet was reduced four weeks later to 3:1, and then after an interval of five weeks to 2½:1. Finally at the end of six months the ratio was decreased to 2:1. During the spring E. S. had a sore throat and her temperature rose to 102-103 degrees. As she did not act particularly sick, the diet was continued unchanged, and no other symptoms developed.

This child gained consistently and rapidly in weight throughout treatment and continued to be well during all dietary changes. One year and 11 months after the beginning of treatment her weight was 93 pounds and her height 59½ inches. There had been complete freedom from attacks for one year and six months.

In Table XXV are given sample menus for breakfast, dinner, and supper for this patient while on the diets of various ratios and caloric contents.

TABLE XXV

SAMPLE MENUS ILLUSTRATING THE USE BY PATIENT E.S. OF THE KETOGENIC DIET

Ketogenic-Antiketogenic Ratio 1½: 1

Carbohydrate 70 grams
Protein 35 "
Fat 158 "
Calories 1,800 "

Breakfast	C.	P.	F.	Total Calories
2 Triscuits	15.2	2.	..	68.
90 grams 40% cream	3.	3.	36.	348.
150 " grapefruit *or*				
75 " 10% fruit	5.	2.5	..	30.
20 " bacon	..	3.3	10.	103.
8 " butter	..	..	6.6	60.
Bran cakes				
Cocoa shells				
	23.2	10.8	52.6	609.
Dinner				
Broth				
18 grams lean meat	..	4.8	3.	46.
150 " 5% vegetables	5.	2.5	..	30.
60 " 40% cream	2.	2.	24.	232.
10 " pecans	1.9	1.6	10.6	114.
120 " grapefruit *or*				
60 " 10% fruit	4.	2.	..	24.
2 Uneedas	10.	1.	1.	52.
18 grams butter	..	..	15.	135.
	46.1	24.7	106.2	1,242.
Supper				
Broth				
150 grams 5% vegetables	5.	2.5	..	30.
60 " 40% cream	2.	2.	24.	232.
10 " peanut butter	1.7	2.9	4.7	60.
150 " grapefruit *or*				
75 " 10% fruit	5.	2.5	..	30.
2 Uneedas	10.	1.	1.	52.
27 grams butter	..	..	22.5	202.
	69.8	35.6	158.4	1,848.

TABLE XXV—(*Continued*)

SAMPLE MENUS ILLUSTRATING THE USE BY PATIENT E.S. OF THE KETOGENIC DIET

Ketogenic-Antiketogenic Ratio 2½: 1

Carbohydrate 36 grams
Protein 40 "
Fat 190 "
Calories 2,000

Breakfast	C.	P.	F.	Total Calories
1 egg	..	6.	6.	78.
90 grams 40% cream	3.	3.	36.	348.
240 " grapefruit *or*				
120 " 10% fruit	8.	4.	..	32.
26 " butter	..	..	21.6	195.
Bran cakes				
Cocoa shells				
	11.	13.	63.6	653.
Dinner				
Broth				
30 grams lean meat	..	8.	5.	77.
60 " 40% cream	2.	2.	24.	232.
120 " 5% vegetables	4.	2.	..	24.
10 " pecans	1.9	1.6	10.6	114.
1 Uneeda	5.	.5	.5	26.
10 grams olive oil	..	..	10.	90.
16 " butter	..	..	13.3	120.
D-Zerta				
	23.9	27.1	127.0	1,336.
Supper				
Broth				
120 grams 5% vegetables	4.	2.	..	24.
60 " 40% cream	2.	2.	24.	232.
10 " almonds	1.5	2.1	5.4	63.
1 Uneeda	5.	.5	.5	26.
25 grams cheese	..	6.6	9.1	109.
10 " olive oil	..	..	10.	90.
17 " butter	..	..	14.1	127.
	36.4	40.3	190.1	2,007.

TABLE XXV—(*Continued*)

SAMPLE MENUS ILLUSTRATING THE USE BY PATIENT E.S. OF THE KETOGENIC DIET

Ketogenic-Antiketogenic Ratio 3½:1

Carbohydrate 16 grams
Protein 43 "
Fat 207 "
Calories 2,100

Breakfast	C.	P.	F.	Total Calories
1 egg	..	6.	6.	78.
60 grams 40% cream	2.	2.	24.	232.
90 " grapefruit *or*				
45 " 10% fruit	3.	1.5	..	18.
25 " bacon	..	4.1	12.5	129.
10 " butter	..	..	8.3	75.
19 " olive oil	..	..	19.	171.
Cocoa shells				
Bran cakes				
	5.	13.6	69.8	703.
Dinner				
Broth				
45 grams lean meat	..	12.	7.5	115.
90 " 5% vegetables	3.	1.5	..	18.
30 " 40% cream	1.	1.	12.	116.
10 " pecans	1.9	1.6	10.6	114.
20 " olive oil	..	..	20.	180.
22 " butter	..	..	18.3	165.
D-Zerta				
	10.9	29.7	138.2	1,411.
Supper				
Broth				
1 egg	..	6.	6.	78.
60 grams 5% vegetables	2.	1.	..	12.
30 " 40% cream	1.	1.	12.	116.
90 " grapefruit *or*				
45 " 10% fruit	3.	1.5	..	18.
15 " cheese	..	4.	5.5	65.
25 " olive oil	..	..	25.	225.
25 " butter	..	..	20.8	187.
	16.9	43.2	207.5	2,112.

TABLE XXV—(*Continued*)

SAMPLE MENUS ILLUSTRATING THE USE BY PATIENT E.S. OF THE KETOGENIC DIET

Ketogenic-Antiketogenic Ratio 3½:1

Carbohydrate 22 grams
Protein 46 "
Fat 236 "
Calories 2,400

Breakfast	C.	P.	F.	Total Calories
1 egg	..	6.	6.	78.
60 grams 40% cream	2.	2.	24.	232.
150 " grapefruit *or*				
75 " 10% fruit	5.	2.5	..	30.
30 " bacon	..	5.	15.	155.
15 " butter	..	..	12.5	112.
21 " olive oil	..	..	21.	189.
Cocoa shells				
Bran cakes				
	7.	15.5	78.5	796.
Dinner				
Broth				
40 grams lean meat	..	10.6	6.6	102.
90 " 5% vegetables	3.	1.5	..	18.
60 " 40% cream	2.	2.	24.	232.
10 " pecans	1.9	1.6	10.6	114.
20 " olive oil	..	..	20.	180.
21 " butter	..	..	17.5	157.
D-Zerta				
	13.9	31.2	157.2	1,599.
Supper				
Broth				
1 egg	..	6.	6.	78.
60 grams 5% vegetables	2.	1.	..	12.
60 " 40% cream	2.	2.	24.	232.
120 " grapefruit *or*				
60 " 10% fruit	4.	2.	..	24.
15 " cheese	..	4.	5.5	65.
25 " olive oil	..	..	25.	225.
23 " butter	..	..	19.1	172.
	21.9	46.2	236.8	2,407.

CHAPTER XVII

Detailed Management of the Diet

To provide attractive meals without overstepping the limits set by a prescribed diet requires a little training and much ingenuity. Experience shows that the most satisfactory method of fulfilling the requirements of a special diet is to outline in detail the theoretical composition of the meals and then by consulting various authorized tables to choose whatever foods most tastefully provide the material needed.

Suppose, for example, the physician has prescribed for a nine-year-old epileptic child a diet of 2000 calories with a ketogenic-antiketogenic ratio of 2.5: 1. In this case there must be 40 grams of protein, 189 grams of fat, and 36 grams of carbohydrate. Each meal is to contain one-third of this daily allowance so that its ketogenic-antiketogenic ratio shall be identical with that of the diet as a whole. Therefore, in each meal there will be 13 grams of protein, 63 grams of fat, and 12 grams of carbohydrate. As soon as this has been determined, the first step to take in the detailed arrangement of the diet is to make up tentative menus which are appetizing to the individual patient. Then, by consulting Table XXII the composition of the various foods may be determined, and their suitability demonstrated. For breakfast,

for example, it might be thought attractive to serve fruit, bacon and egg, toast with butter and jam, and some hot drink. If a tabulation is made of the various constituents of these foods those which overstep the limits of the diet can be excluded. The bacon and egg will at once appear highly suitable since they contain only protein and fat. The butter to be eaten on the toast will be seen to contain only fat, which must be included in the diet in every form possible, and the cream which would naturally be put into the hot drink will be found desirable also, for it contains a large proportion of fat and comparatively little carbohydrate and protein. The other articles chosen will not fall into the scheme of things quite so readily. Certain fruits, for instance, contain so much carbohydrate that they must be given up completely. Others, however, can be used to lend variety to the diet if they are included in small amounts. Toast, of any usual kind, must be ruled out at once. It is so largely composed of carbohydrate that a very small piece would use up the entire carbohydrate allowance for the day. Jam is still more undesirable, for it contains an even greater proportion of carbohydrate. To fulfill the requirements of the diet the hot drink chosen must be free from stimulants. Tea and coffee are, therefore, excluded. Ordinary cocoa, although non-stimulating, contains too much carbohydrate to be desirable, even when it is unsweetened. Thus, it is demonstrated that only part of the original menu is suitable and that some of the foods chosen must be used with caution, or completely excluded and replaced by substitutes. A little experience will show

that it is wise to include the so-called 5 and 10 per cent fruits in the diet. Bread (toast) is always to be entirely replaced by specially prepared bran wafers which are without food value. Jam must be omitted completely. For the hot drink a preparation made from cocoa shells will prove attractive when served with cream. If necessary, it may be sweetened with saccharin, never with sugar. The final breakfast menu, then, will include, fruit, bacon and egg, bran wafers and butter, cocoa shells and cream. Except for the bran wafers and the cocoa-shell preparation, which have no food value, everything must be served in carefully measured amounts, for the theoretical requirements of the diet must be accurately fulfilled. The quantities of the foods to be served in this meal, as well as their content of carbohydrate, protein, and fat, and their caloric value are given in Table XXVI. The accompanying dinner and supper menus (see page 235) have been worked out as was the breakfast menu, with attention to palatability, type, and quantity of food materials. Practice will make it possible to arrange other menus which provide the patient with a variety of foodstuffs without in any way varying the carbohydrate, protein, fat, and caloric content of the meals. In so far as possible, it is wise to serve for breakfast, dinner, and supper the foods normally included in those meals. There is no need for upsetting habitual customs if they can be reconciled with dietary treatment.

Experience has shown, however, that certain concessions must be made if treatment is to be satisfactory, for all normal dietary customs do not adapt

TABLE XXVI

BREAKFAST, DINNER AND SUPPER MENUS WHICH ILLUSTRATE THE USE OF A 2000 CALORY DIET WITH 2½:1 KETOGENIC-ANTIKETOGENIC RATIO FOR A CHILD 9 YEARS OLD

Ketogenic-Antiketogenic Ratio 2½:1

Carbohydrate 36 grams
Protein 40 "
Fat 189 "
Calories 2,000 "

Breakfast	C.	P.	F.	Total Calories
1 Egg	..	6.	6.	78.
90 grams 40% cream	3.	3.	36.	348.
240 " grapefruit *or*				
120 " 10% fruit	8.	4.	..	48.
26 " butter	..	..	21.6	195.
Bran cakes				
Cocoa shells				
	11.	13.	63.6	669.
Dinner				
Broth				
30 grams lean meat	..	8.	5.	77.
60 " 40% cream	2.	2.	24.	232.
120 " 5% vegetables	4.	2.	..	24.
10 " pecans	1.9	1.6	10.6	114.
1 Uneeda	5.	.5	.5	26.
10 grams olive oil	..	..	10.	90.
16 " butter	..	..	13.3	120.
D-Zerta				
	23.9	27.1	127.0	1,352.
Supper				
Broth				
120 grams 5% vegetables	4.	2.	..	24.
60 " 40% cream	2.	2.	24.	232.
10 " almonds	1.5	2.1	5.4	63.
1 Uneeda	5.	.5	.5	26.
25 grams cheese	..	6.6	9.1	109.
10 " olive oil	..	..	10.	90.
16 " butter	..	..	13.3	120.
	36.4	40.3	189.3	2,016.

themselves to the conditions requisite to ketogenic therapy. For the most part, patients must give up desserts and omit entirely the common substitutes for them. If it proves impossible comfortably to go without such foods, special dishes may be prepared. Most of these are far from appetizing, but a few add savor to the diet. The agar-agar jelly described in Joslin's Diabetic Manual [1] (151) may be served with impunity, but is unattractive to most patients.

The sugarless food-free gelatine substance known as D-Zerta, on the other hand, constitutes a fairly satisfactory addition to the essential diet. It provides a pleasant medium for the cream necessarily included in the menu, for just like any other gelatine dessert, it may be served with whipped cream, flavored with vanilla if desired. Sugar must not, of course, be added, but if there is a strong craving for sweet food, saccharin may be used instead. A word of caution should be given here concerning saccharin: in too large quantities its flavor is bitter rather than sweet. If it is used at all, each individual must decide for himself the quantity which produces the most pleasing taste. Of the other commercial preparations for use in special diets few are both attractive and suitable. Sugarless Candy and the so-called Diabetic Candy are, however, innocuous and lend

[1] AGAR-AGAR JELLY

Agar-Agar (powdered)	1 teaspoonful
Water, strained cocoa shells, or coffee	1½ pints
Flavoring extract	1 teaspoonful

Mix agar with a little of the water until a smooth paste. Add rest of water and boil ten minutes. Strain, flavor, color and sweeten with saccharin as desired. Pour into molds and cool at room temperature.

flavor to a meal. They come in various flavors and are entirely without food value. Carbohydrate-free chewing gum also is inert; it has a pleasing peppermint flavor. As yet, no palatable, calory-free cookies or cakes have been devised. Those on the market are soon set aside as being unappetizing. The flavoring extracts may be used when desired. To vary these desserts and sweet foods, few dishes are available. With provision for suitable refrigeration, mousse may be made from part of the cream allowance. It can be flavored with vanilla or a small amount of coffee and saccharin if desired; or in season with some fresh fruit, such as strawberry, raspberry, or peach. Such a dessert is, of course, an integral part of the diet and is in no way to be considered merely an extra, as are some of the commercial preparations.

Inclusion of the requisite amount of fat in the meals is frequently difficult, for only a certain proportion of what is ordinarily considered food can be composed of fat and oil. When an excess must be consumed it is necessary for the patient to take a "dose" of some suitable nutritive oil with each meal. This proves far pleasanter than mixing a corresponding amount of fat with the rest of the food. Olive oil or cod-liver oil may be employed for this purpose. Children find cod-liver oil by far the more palatable. A few of the methods of incorporating fatty substances in food should be mentioned. A small amount of olive oil may be mixed with orange juice in the morning and butter and cream may be added to chicken broth without diminishing their attractive-

ness. Butter and cream may be served with cooked vegetables, but only when added from the ration after the portion for the meal has been weighed out. Eggs may be prepared in various ways with butter and cream. In no case, however, are butter, cream, or nutritive oils to be added in unknown quantities to the diet. If an egg is fried, for example, mineral oil must be used in the pan, for there is no practical means of measuring the amount of fat absorbed during cooking. The same is true in the preparation of an omelet. Non-nutritive oil must be employed to grease the pan, although in mixing the omelet much cream and butter may be added. Because of the difficulty in measuring the oil in a given quantity of mayonnaise, it is wise to prepare the dressing with mineral oil. It can then be used without stint, for the caloric value of the other ingredients is negligible. Attractive mayonnaise may be made from the following recipe:

MAYONNAISE DRESSING

Yolk of 1 Egg
2 Cups Mineral Oil
2 Tbspn. Vinegar
Juice of ½ Lemon
½ Tspn. Mustard
Salt, Paprika

Beat yolk, add seasonings, then add oil drop by drop, beating constantly. When too thick to beat well, begin adding ½ teaspoon of vinegar alternately with oil, keeping of proper consistency. Total amount of vinegar may not be required.

If preferred, an equally satisfactory dressing may be bought ready to use. Diabetic Salad Dressing is also

without food value and need not, therefore, be measured. French dressing is on the whole unsatisfactory for children's diets. The quantity of oil made into it can be easily measured, but in most instances salad served with it is less appetizing to the patient than that served with mayonnaise. Other methods of solving the problems of the measurement and incorporation of fat in the food cannot be formally discussed. Each individual responsible for the preparation and maintenance of a ketogenic diet must learn the details by experience. Only care and ingenuity make it possible attractively to fulfill the requirements.

Whenever the ketogenic-antiketogenic ratio is 2½: 1 or higher, special attention must be paid to the mineral-salt content of the diet. Certain salts, for instance those of calcium, are essential for the growth and upkeep of the body and if health is to be maintained adequate amounts must be present in the food except during very brief periods. As can be seen from Table XXVII, abstinence from many of the articles of diet which contain a large proportion of these salts is necessary during ketogenic therapy. This abstinence is essential in that it permits the development of the desired ketosis: in that it deprives the body of needed salts it is much to be regretted. To compensate for the calcium deficiency of diets with a ratio of 2½: 1 or higher a daily dose of 5 grains of calcium may be given. As the metabolism of other salts is less fully understood it is more difficult to provide supplementary medication.

TABLE XXVII

ASH CONSTITUENTS OF FOODS IN PERCENTAGE OF THE EDIBLE PORTION ***

Food	Calcium (Ca)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Phosphorus (P)	Chlorine (Cl)	Sulphur (S)	Iron (Fe)
Almonds	.239	.251	.741	.019	.465	.037	.160	.0039
Apples	.007	.008	.127	.011	.012	.005	.006	.0003
Asparagus	.025	.011	.196	.007	.039	.039	.041	.0010
Bacon	.006	.012	.169	.042	.108	.038	.115	.0015
Bananas	.009	.028	.401	.034	.031	.125	.010	.0006
Barley, entire	.043	.141	.477	.076	.400	.016	.153	.0041
Beans, Kidney, dry	.132	.139	1.144	.041	.475	.041	.227	.0072
Beans, Lima, fresh	.028	(.070)	(.613)	(.088)	.133	(.009)	(.057)	.0020
Beans, string	.046	.025	.247	.019	.052	.024	.030	.0011
Beef, lean	.012	.024	.338	.084	.216	.076	.230	.0030
Beets	.029	.021	.353	.093	.039	.058	.016	.0006
Blackberries	.017	.021	.169	(.007)	.034	(.010)	.020	.0006
Blueberries	.020	.007	.051	.016	.008	.008	.011	.0009
Bread, wheat	(.05)	(.05)	(.208)	(.394)	(.175)	(.607)	(.120)	(.0016)
Bread, graham	(.05)	(.05)	(.291)	(.394)	(.218)	(.607)	.150	(.0025)
Bread, rye	.024	.039	.151	.701	.148	1.025	.104	(.0016)
Bread, white	.027	.023	.108	(.394)	.093	(.607)	.105	.0009
Brussels sprouts	.027	.040	.375	.004	.120	.040	.194	(.0011)
Butter	.015	.001	.014	(.788)	.017	(1.212)	(.010)	.0002
Buttermilk	.105	.016	.151	.064	.097	.099	.026	.00025
Cabbage	.045	.015	.247	.027	.029	.024	.066	.0011
Cantaloupe	.017	.012	.235	.061	.015	.041	.014	.0003
Carrots	.056	.021	.287	.101	.046	.036	.022	.0006
Cauliflower	.123	.014	.222	.068	.061	.050	.086	.0006

Caviar	.137	.022	.422	.874	.176	1.819	...	...
Celery	.078	.014	.316	.084	.037	.156	.022	.0005
Chard	.150	.071	.318	.086	.040	.039	.124	(.0025)
Cheese	.931	.037	.089	.606	.683	880	.263	.0013
Cherries	.019	.016	.213	.023	.031	.014	.011	.0004
Corn, sweet	.006	.033	.113	.040	.103	.014	.046	.0008
Crackers	.022	.011	.100	(.594)	.102	(.910)	.125	.0015
Cranberries	.018	.007	.077	.010	.013	.009	.007	.0006
Cream	.086	.010	.126	.035	.067	.080	.030	.00022
Cucumbers	.016	.009	.140	.010	.033	.030	.020	.0002
Dandelion	.105	.036	.461	.168	.072	.099	.017	.0027
Dates	.065	.069	.611	.055	.056	.228	.070	.0030
Eggplant	.011	.015	(.140)	(.010)	.034	.024	.016	.0005
Eggs	.067	.011	.140	.143	.180	.106	.195	.0030
Egg White	.015	.010	.160	.156	.014	.155	.216	.0001
Egg Yolk	.137	.016	.115	.075	.524	.094	.166	.0086
Endive	.104	.013	.380	.109	.038	.167	.035	....
Fish *								
Grapefruit	.021	.009	.161	.004	.020	.005	.010	.0003
Grapes	.019	.010	.197	.015	.031	.005	.024	.0003
Hazelnuts	.287	140	.618	.019	.354	.067	.198	.0041
Lemons	.036	.007	.175	.004	.022	.002	.011	.0006
Lettuce	.043	.017	.339	.027	.042	.074	.014	.0007
Meat **								

* Average fish is estimated to contain per 100 grams of protein as follows: 0.109 gram Ca; 0.133 gram Mg; 1.671 grams K; 0.373 gram Na; 1.148 grams P; 0.528 gram Cl; 1.119 grams S; 0.0055 gram Fe.

** Average meat is estimated to contain per 100 grams protein as follows: 0.058 gram Ca; 0.118 gram Mg; 1.694 grams K; 0.421 gram Na; 1.078 grams P; 0.378 gram Cl; 1.146 grams S; 0.0150 gram Fe.

*** Taken from: *Chemistry of Food and Nutrition*, by Henry C. Sherman, Ph.D., Sc.D.

Brackets indicate that data are based in part at least on assumptions.

TABLE XXVII—(*Continued*)

Food	Calcium (Ca)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Phosphorus (P)	Chlorine (Cl)	Sulphur (S)	Iron (Fe)
Milk, whole	.120	.012	.143	.051	.093	.106	.034	.00024
Mushrooms	.017	.016	.384	.027	.108	.021	.051	....
Muskmelon	.017	.012	.235	.061	.015	.041	.014	.0003
Oatmeal	.069	.110	.344	.062	.392	.069	.202	.0038
Okra	.071	.010	.035	.043	.019	...	...	....
Olives	.122	.002	1.526	.128	.014	.004	.027	.0029
Onions	.034	.016	.178	.016	.045	.021	.070	.0006
Oranges	.045	.012	.177	.012	.021	.006	.011	.0002
Oysters	.052	.037	.091	.459	.155	.590	.187	.0045
Parsnips	.059	.034	.518	.004	.076	.030	.036	.0006
Peaches	.016	.010	.214	.022	.024	.004	.009	.0003
Peanuts	.071	.180	.654	.050	.399	.056	.224	.0020
Pears	.015	.011	.132	.016	.026	.011	.010	.0003
Peas, fresh	.028	.038	.285	.013	.127	.024	.063	.0017
Pecans	.089	.152	(.332)	...	.335	.050	.113	.0026
Pepper, green, fresh	.006	.010	(.139)	...	.026	.013	.014	.0004
Pineapple	.018	.011	.321	.016	.028	.051	.009	.0005
Plums	.020	.011	.203	.019	.032	.002	.009	.0005
Potatoes	.014	.028	.429	.021	.058	.038	.030	.0013
Prunes, dried	.054	.055	1.030	.069	.105	.017	.037	.0030
Radishes	.021	.012	.218	.069	.029	.054	.041	.0006
Raisins	.064	.083	.820	.133	.132	.082	.051	.0021
Raspberries	.049	.024	.173	...	.052	...	.017	.0006
Rhubarb	.044	.017	.325	.025	.031	.036	.013	.0010
Rice, white	.009	.033	.070	.025	.096	.054	.117	.0009

TABLE XXVII—(*Continued*)

Romaine	.045	.032	.306	.016	.053	.073	.019	....
Shredded wheat	.041	.144	...	...	.324	...	...	.0045
Shrimp	.096	...	...	...	...	...	...	....
Spinach	.067	.037	.774	.125	.068	.074	.038	.0036
Squash, summer	.024	.012	.180	.004	...	...	...	(.0006)
Squash, winter	.019	.011	.320	.004	...	...	...	(.0006)
Strawberries	.041	.019	.147	.050	.028	.006	.014	.0008
Tomatoes	.011	.010	.275	.010	.026	.034	.014	.0004
Turnips	.064	.017	.338	.056	.046	.041	.065	.0005
Vinegar	.016	.008	.165	...	.013	...	.017	(.0003)
Walnuts	.089	.134	(.332)	...	.358	.040	.172	.0021
Water cress	.187?	.034	.287	.099	.005	.061	.167	.0019
Watermelon	.011	.003	.073	.008	.003	.008	.007	

The vitamin content of ketogenic foods varies greatly, but on the whole is adequate for bodily requirements if menus are arranged with care. By consulting Table XXVIII the content of different foods can be determined and a proper balance maintained. Certain articles of diet contain only one vitamin, others none of this, but a considerable quantity of other vitamins. By including such supplementary substances in the diet serious lacks can easily be avoided.

To allay the discomforts which result from undue concentration of food, care must be taken to supply sufficient bulky matter in the diet. This will do away with a constant sense of hunger and will make the patient much more comfortable. It also tends to prevent constipation.

In choosing the proteins to be used, care should be taken to provide, for the most part, those which are readily absorbed by the body. These are in general derived from animal rather than from vegetable food. The protein content of common foods is shown in Table XXII.

A brief list of dishes which may be prepared without "breaking diet" may perhaps suggest other appetizing foods to the person responsible for planning a ketogenic diet. Attention to variety is important in that it may prevent loss of appetite. The following dishes may be prepared with the foods included in the ketogenic diet: tomato relish, scalloped tomato, fried fresh tomato, stuffed tomato salad, chicken or fish salad, beef or lamb croquets, chicken à la King, scrambled egg with tomato, cheese

TABLE XXVIII

FOODS AS SOURCES OF VITAMINS A, B, AND C

\+ indicates that the food contains the vitamin.
\+ + indicates that the food is a good source of the vitamin.
\+ + + indicates that the food is an excellent source of the vitamin.
— indicates that the food contains no appreciable amount of the vitamin.
? indicates doubt as to presence or relative amount.
* indicates that evidence is lacking or appears insufficient.

Food	Vitamin A	Vitamin B	Vitamin C
Almonds	+	++	*
Apples, raw	+	+ to ++	++
Artichoke, French	++	+	*
Asparagus	*	+++?	*
Avocado (alligator pear)	+	++	*
Bacon	— to +	+ to ++	?
Bananas	+ to ++	+ to ++	++
Barley, whole	+	++	—
Beans, kidney	+	+++	*
Beans, string, fresh, raw	++	++	++
Beans, string, cooked	++	++	*
Beechnuts	*	++	*
Beef	+	++	— to +
Beef juice	*	+	— to +
Beets (roots)	+	+	+
Beet leaves	++	++	*
Beet stems	*	+	*
Brazil nuts	+	++	*
Bread, white, water	?	+	—
Bread, white, milk	+	+	— to +
Bread, whole wheat, water	+	++	?
Bread, whole wheat, milk	++	++	— to +
Butter	+++	—	—
Buttermilk	+	++	+ variable
Cabbage, green, raw	++	++	+++
Cabbage, head, raw	+	++	+++
Cabbage, head, cooked	+	++	+
Cabbage, head, dried	+ to ++	++	+
Cabbage, head, canned	+	++	+
Cantaloupe	++	++	*
Carrots, fresh, young	+++	++	++
Carrots, old, raw	+++	++	+
Cauliflower	+	++	+
Celery, bleached stems	— to +	++	*

The above table is taken from *Chemistry of Food and Nutrition,* by Henry C. Sherman, Ph.D., Sc.D., 1928.

TABLE XXVIII—(*Continued*)

Food	Vitamin A	Vitamin B	Vitamin C
Chard	++	+ to ++	*
Cheese, whole milk	++ to +++	−?	*
Cheese, cottage (skim)	+	*	*
Coconut	+	++	*
Coconut oil	− to +	−	−
Codliver oil	+++	−	−
Corn meal	− to +	−	−
Cranberry (or juice)	*	*	+
Cream	+++	++	+ variable
Cress	*	*	+
Cucumber	− to +	+	++?
Dandelion greens	++	++	+
Eggs	+++	+ to ++	−?
Egg white	−	*	−?
Egg yolk	+++	++	−?
Egg plant	+	+	*
Endive	+	*	+
Fish, fat	+	+	*
Fish, lean	− to +	+	*
Flour, white	−	− to +	−
Flour, whole wheat	+	++	−
Grains, whole, dry	+	++	−
Grapefruit (or juice)	+	++	+++
Grapes	+	+ to ++	+
Ham	− to +	++	−
Lemon juice	+	++	+++
Lettuce	+ to ++	++	+++
Liver	++ to +++	++	+
Meat, canned	− to +	+	−
Meat extract	−	−?	−
Milk (whole)	+++	++	+ variable
Milk, scalded	+++	++	+ variable
Milk, fresh, skim	+	++	+ variable
Mushrooms	−	++	−
Mutton	− to +	++	*
Oatmeal	− to +	++	−
Okra	*	+++?	*
Olive oil	− to +	−	−
Onions, raw	− to +	+	++
Onions, cooked	− to +	+	+
Orange juice	+	++	+++
Oysters	*	*	+
Parsley	*	++	*
Peaches, raw	+	+ to ++	++
Peanuts	+	++	*
Peanut butter	+	++	*
Pears	*	+	*

TABLE XXVIII—(*Continued*)

Food	Vitamin A	Vitamin B	Vitamin C
Peas, young, green, raw ..	++	++	+++
Peas, canned	++	++	++
Peas, dry	+	++	?
Pecans	+	+	*
Peppers, green	++	*	*
Pineapple, fresh	++	++	++
Pineapple, canned	++	++	++?
Pork	− to +	+++?	−
Potatoes, sweet	++	++	++
Potatoes, white, raw	+	++	++
Potatoes, white, boiled ...	+	++	++
Potatoes, white, baked ...	+	++	+ to ++?
Prunes	++	++	−
Pumpkin	+	+	+
Radish	− to +	+	*
Raisins	−	+	−
Raspberries	*	*	++
Rhubarb	*	*	+
Rice (polished) white	−	−	−
Rice, whole grain	+	++	−
Roe, fish	++	++	?
Romaine	++	++	*
Rye, whole	+	++	−
Salmon, canned	+	*	*
Sauerkraut	+	+	−?
Shrimp	+	*	*
Spinach, cooked	+++	+++	+
Hubbard Squash	++	*	*
Strawberries	*	+	+ to ++
Sugar	−	−	−
Sweetbreads	+	+	*
Tangerines	*	*	+++
Tomato, raw or canned ..	++	++	+++
Turnip, white	− to +	++	++
Veal	− to +	+?	*
Walnuts	+	++	*
Wheat flour, white	−	+?	−
Wheat, whole	+	++	−

omelet, cream soups, oyster stew, cold slaw, custard, grapefruit mixed with very finely grated brazil nuts.

The actual cooking of food for the ketogenic diet is quite comparable to that of ordinary food. Clear lamb, beef, and chicken broth are made without

vegetables or rice. Before being served they should be cooled so that the fat may be removed. Vegetables must in some instances be prepared without salt, but this is unnecessary except by special order of the physician. If served with butter or cream, the quantities of these substances must be carefully measured and taken from the allowance for the meal. They should be added after the cooked vegetables have been weighed out and placed upon the dish in which they are served. For the most part, the so-called 5 per cent vegetables (see Table XXIX) must be used, but once in a while to vary the menu it will be found advisable to substitute a comparable amount, *i.e.*, one-half of the weight of a 10 per cent vegetable. Salads may be prepared as in the normal diet, except that special dressing is to be used as has already been mentioned. For most patients they seem to be particularly appetizing for supper. If desired, they may constitute the main course of the meal, and be made from the egg, fish, or vegetables to be included in that meal. Except for the fact that meats must not be cooked with sauces of any kind, they require no special preparation. They are in all cases to be weighed after cooking. Care must be taken to ascertain that only lean meat is included in the material weighed. A lamb chop, for instance, is not to be used as a whole: everything except the lean portion is to be discarded before weighing. No restriction need be placed upon the choice of meat, but if liver or sweetbreads are given, their additional carbohydrate content must be recognized in the calculation of the diet. (See Table XXII.) The bran

TABLE XXIX

AN INCOMPLETE BUT USEFUL TABLE OF THE COMPOSITION OF VARIOUS COMMON FOODS *

Water, clear broths, coffee, tea, cocoa shells and cracked cocoa can be taken without allowance for food content

FOODS ARRANGED APPROXIMATELY ACCORDING TO CONTENT OF CARBOHYDRATES

	5%		10%	15%	20%
* Reckon average carbohydrate in 5% veg. as 3%—of 10% veg. as 6%					
VEGETABLES (fresh or canned)	1%-3%	3%-5%	10% *	15%	20%
	Lettuce	Tomatoes	String Beans	Green Peas	Potatoes
	Cucumbers	Brussels Sprouts	Pumpkin	Jerusalem Artichokes	Shell Beans
	Spinach	Water Cress	Turnip	Parsnips	Baked Beans
	Asparagus	Sea Kale	Kohl-Rabi	Lima Beans very young	Green Corn
	Rhubarb	Okra	Squash		Boiled Rice
	Endive	Cauliflower	Beets		Boiled Macaroni
	Marrow	Egg Plant	Carrots		
	Sorrel	Cabbage	Onions		
	Sauerkraut	Radishes	Green Peas very young		
	Beet Greens	Leeks			
	Dandelions	String Beans very young			
	Swiss Chard	Broccoli			
	Celery	French Artichokes			
	Mushrooms				
FRUITS	Ripe Olives (20% fat)		Strawberries	Raspberries	Plums
	Grape Fruit		Lemons	Currants	Bananas
			Cranberries	Apricots	Prunes
			Peaches	Pears	
			Pineapple	Apples	
			Blackberries	Blueberries	
			Oranges	Cherries	

1 gram protein, 4 calories.
1 " carbohydrate, 4 "
1 " fat, 9 "
6.25 " protein contain 1g. nitrogen.

1 kilogram = 2.2 pounds.
30 grams g. or cubic centimeters c.c. = 1 ounce.
A patient "at rest" requires 25 calories per kilogram

30 Grams 1 oz. Contain Approximately	Carbohydrates G.	Protein G.	Fat G.	Calories
Vegetables 5%	1	0.5	0	6
Vegetables 10%	2	0.5	0	10
Shredded Wheat (3 triscuits)	23	3	0	104
Uneedas, two (6 to 1 oz.)	10	1	1	53
Potato	6	1	0	28
Bread	18	3	0	84
Oatmeal, dry wgt.	20	5	2	118
Oysters, six	4	6	1	49
Milk	1.5	1	1	19
Meat (cooked, lean)	0	8	5	77
Fish	0	6	0	24
Chicken (cooked lean)	0	8	3	59
Egg (one)	0	6	6	78
Cheese	0	8	11	131
Bacon	0	5	15	155
Cream, 20%	1	1	6	62
Cream, 40%	1	1	12	116
Brazil Nuts	2	5	20	208
Butter	0	0	25	225
Oil	0	0	30	270

Thomas Groom & Co., Inc., 105 State St., Boston, Mass.

* Taken from Dr. Elliott P. Joslin's Diet Card Form J-13 3-27. Published by Thomas Groom & Co., Inc., Boston, Mass.

wafers which are a non-nutritive substitute for bread may be made from the following recipe:

BRAN WAFERS

Washed Bran	3 cups
Powdered India Gum	3 tbspn.
Cinnamon	2 tspn.
Saccharin (dissolved in water)	1 gram

Mix the dry ingredients together, then add enough hot water to make a paste that can be spread on a baking sheet. Cut this in squares and dry in a moderate oven for 2 or 3 hours. If an attempt is made to bake these more quickly they will burn before they are crisp.

The preparation of a palatable drink from cocoa shells is not difficult, but requires a little knack. If the infusion is too weak it will make a most unattractive beverage, and if it is too strong it will have a bitter flavor. The majority of people find the best recipe to be:

1 Cup of Cocoa Shells
1 Quart of Cold Water

Mix the water and shells, bringing slowly to a boil, and allow the mixture to simmer gently or remain on the back of the stove without boiling for between 1 and 2 hours.

Thus, aside from the facts that a few special recipes must be used and that foods are not to be indiscriminately mixed together in cooking, few restrictions are involved in the actual preparation of the ketogenic diet. The planning and weighing of the food are far more complicated than the cooking.

Because the value of ketogenic treatment depends so largely on the accuracy with which the diet is

planned and weighed, it is well to emphasize certain points. For ease in calculation, grams rather than ounces are employed as the units of weight. Gram scales must therefore be at hand when the meals are served. These vary greatly in cost, but those of moderate price are sufficiently exact for dietary purposes. In the actual measuring out of portions, various rules must be followed. Each dish in which food is to be placed must be counterbalanced while it is still dry and empty, so that the weight of the food put in it may be known. As similarity in size and design does not signify equality in weight every dish must be weighed individually if arbitrary and unintentional variations in the caloric content of the food are to be avoided. Cooked foods are always measured *after* cooking, and never in the raw state. Every article of diet must be measured separately, and absolutely no unweighed material, except certain recognized non-nutritive foods (bran wafers, clear cocoa shells, and mayonnaise dressing, for example), are to be included in any meal. If part of the carbohydrate allowance is given in the form of crackers, only those kinds which have been analyzed should be employed. Similarity in size and shape is not necessarily an indication of similarity of composition. The cream added to cocoa, broth, or the prepared desserts is in no way an addition to the prescribed allowance. The same holds true for butter, nuts, and cheese as well as for all other foods which may in the ordinary diet be considered incidental supplements. Adherence to the letter as well as the spirit of the law is necessary if treatment is to be successful.

To prevent mistakes and the inclusion of undesirable substances in the diet is never easy, even in a hospital where conditions are particularly favorable. Unexpected pitfalls seem to appear in both the kitchen and the rest of the environment. Careful supervision and organization in the kitchen, of course, greatly facilitate exact adherence to a diet. Watch must be incessant, however, if all infringements are to be prevented, for patients quite innocently get hold of illegitimate carbohydrate, protein, and fat from the most unexpected sources. Toothpaste, for instance, invariably contains sugar, and if not completely rinsed from the mouth may render futile all the bothersome dietary measures. Children who have been subjected for a long time to a diet may try to eat it. Most chewing gums, with the exception of spruce gum, are sweetened with sugar. That carbohydrate may also be derived from the coating of pills is another point to remember in the supervision of a patient undergoing ketogenic therapy. The necessary cathartics and other medicines must be chosen with this in mind. Thus, it can be seen that even with full coöperation of the patient the most searching attention must be paid to detail if the ketogenic-antiketogenic ratio is to be maintained.

To avoid constipation all epileptics should be required as a routine to take one dose of Carlsbad salts weekly. If this is not sufficient to keep the bowels in good condition one of the following sugar-free cathartics may be used between times in suitable doses.

CATHARTICS WITHOUT SUGAR

Haley's M'O—Milk of Magnesia and Russian oil in equal parts.
Cascara tablets (uncoated).
Milk of Magnesia.
Plain Granular Agar-Agar.
Various Mineral Oils.
Diabetic or Plain Petrolagar.
Salts (Carlsbad or Epsom).
Bitter Fluid Extract of Cascara.
Castor Oil.

In no instance is there justification for allowing constipation to persist. It demands immediate attention whenever it develops, and all possible measures must be taken to prevent its onset. For some reason its effects are peculiarly deleterious in epilepsy.

As a means of checking the degree of ketosis, frequent analysis of the urine is desirable. After a little instruction and practice most patients can carry out the routine analyses for themselves. The various methods have already been described on page 208. Those most satisfactory for the use of untrained individuals are the ferric chloride test and the sodium nitroprusside test. Others, which are more sensitive, require special apparatus and technical skill. They are needlessly accurate for the purpose of demonstrating the effectiveness of ketogenic therapy. If they are to be used at all they should be carried out by skilled workers in the laboratory.

Clinical Effect of Ketogenic Diets on Digestion.—The change from the usual normal diet which contains large amounts of carbohydrate and relatively small amounts of fat to a strong ketogenic diet (*e.g.*,

ketogenic-antiketogenic ratio of 4: 1) is so great that it is accompanied by marked alteration in the character of digestion and in the need for the different digestive juices. If the shift is sudden, vomiting, colicky cramps and gas pains, diarrhea, constipation, and loss of appetite may ensue. For this reason dietary changes are made gradually in order to allow time for the digestion to accustom itself and to become adjusted to the new conditions. During ketogenic therapy the need for the carbohydrate-splitting ferments is reduced to a minimum, and the burden of digestion is placed on the fat-splitting ferments and the bile. The metabolism is completely changed.

It is possible to make the dietary changes more rapidly in the hospital where the patient is under constant supervision than in the home; and at times under favorable conditions a 4: 1 ratio can be safely reached by the end of a fortnight. Dietary therapy which is carried out at home with weekly supervision by the physician or nurse must progress so much more slowly that six to twelve weeks are usually necessary for all the changes.

Vomiting does not often accompany changes which are made slowly; while it nearly always results when they are too rapid. If it does occur proper measures taken immediately will give complete relief, but if treatment is delayed the special diet must be given up and the digestion allowed to readjust itself to normal conditions. When a patient vomits it is best to omit one or two meals entirely and to allow only water to be taken. If nausea appears without

vomiting the amount of food in each meal should be cut in half until the appetite returns. These measures involve proportionate reduction in the quantity of *all* the food elements (carbohydrate, fat, and protein) to assure maintenance of the desired ketogenic-antiketogenic ratio.

During the later stages of dietetic treatment, patients sometimes complain of abdominal cramps, colic, and intestinal gas. Occasionally these symptoms become so severe as to resemble appendicitis, and it is then necessary to call upon a physician for diagnosis. If he finds no evidence of local disturbance in the appendix, brisk catharsis should be employed and will usually effect a cure. Sometimes it is wise for the patient to go without one or two meals. If the symptoms persist in spite of such treatment, daily administration of bismuth may be effective. It may be given to children as milk of bismuth in two-teaspoonful doses, and to adults as bismuth subcarbonate in 5-grain doses. Since most patients who suffer from colic and gas pains have very poor body posture, correction of the bodily mechanics is often desirable. This may be accomplished by suitable exercises and by the use of orthopedic supports (44). It frequently prevents the retention of gas which is responsible for the other symptoms.

In epileptics, loss of appetite may result from many causes just as it does in normal individuals. The treatment for it depends on the cause. If it is due to fatigue, longer rest periods are needed, while if due to lack of exercise, more strenuous activities should be recommended. When over-eating is the

cause, the caloric content of the diet must be reduced temporarily or even permanently. Because the ketogenic diet is, of necessity, monotonous and uninteresting, it is desirable to prepare and serve all food as attractively as possible. With ingenuity, a great deal can be done to stimulate the appetite by providing variety even within the bounds of a severely restricted regimen. Occasionally in addition to all other measures to arouse the appetite it is wise to prescribe tincture of nux vomica in doses appropriate to the age of the patient.

Relief of constipation is still another factor which affects the appetite. The most desirable methods of treating or avoiding this have already been outlined elsewhere (see page 83), but it may be pointed out here that the chief reliance is to be placed on the effect of bran and mineral oil. If the ordinary medicinal laxatives are used they must be sugar-free. Since weekly administration of salts is a routine measure in epileptic therapy, there is usually no difficulty in keeping the bowels free from residue, but in occasional instances the tendency to constipation is very persistent. At times intestinal stasis is associated with bad posture and relief is obtained by supporting the abdomen with the anterior-posterior pad.

The Use of Drugs with the Ketogenic Diet.—Since the object of dietary therapy is to stop epileptic attacks without the use of drugs, neither the bromides nor luminal are habitually administered during the ketogenic régime. Their effectiveness in conjunction with dietary restrictions has, however, been

tested and experience seems to demonstrate that the bromides are of no value while ketosis is maintained. Luminal, on the other hand, occasionally proves beneficial when given with the diet. Since, as has already been pointed out, it is unwise and even dangerous suddenly to stop administration of luminal when it has been taken for a long time, patients not infrequently begin ketogenic therapy while continuing with drug therapy. It is very rare for a patient with epilepsy of long standing to come for treatment when free from the effects of luminal. Usually therefore it is necessary to continue administration of the habitual dose of luminal until definite ketosis has developed. Then the quantity of luminal given can gradually be reduced by ½ or ¼ grain (30-15 mg.) at a time until at the end of a few weeks or months no further doses of the drug are required. On the whole, it may be said that patients are better off without luminal, but occasionally small daily doses continue to be helpful, or small amounts are of benefit when taken irregularly on days of unusual excitement or nervous fatigue.

Thyroid extract may be given to patients with lowered basal metabolism, but in only a very few instances is it of distinct value.

The Ketogenic Diet and Intercurrent Illnesses.—It has long been known that epileptic seizures tend to disappear during intercurrent illnesses and after etherization,—a fact which is of special importance in the management of epilepsy during childhood when exposure and lack of immunity make intercurrent illness more frequent than during adult

life. Experience shows that, whenever the symptoms of these illnesses make it desirable, dietary regulations can be overstepped with impunity, even until ketosis is entirely done away with. Administration of orange juice, ginger ale, cereals, or other carbohydrates quickly satisfies the sugar needs of the body, and may easily relieve symptoms which otherwise would prove very resistive to treatment. If carbohydrates are given for only a few days at a time, it is possible to return to the most recently employed ketogenic diet directly without the intermediate steps that are essential in the first establishment of the diet; but if they are needed for long periods ketosis must be reinduced gradually. When the intercurrent illness is mild and the digestion continues to be good, infringements upon the dietary regulations are not necessary. Many patients have had infections of the upper respiratory tract, scarlet fever, chicken-pox and measles without requiring interruption of the treatment for epilepsy.

If the need for etherization and operation can be foreseen, it is safer to prepare the patient for the ordeal by building up the carbohydrate reserve for a few hours just as is done in the case of normal individuals. This partially reduces the strain involved in the operation, and, in so far as has been observed, in no way alters the favorable course of the dietary treatment. If such preparation is impossible, of course, the extra risk must be run and the patient submitted to etherization and operation at once.

Clinical Results to be Expected.—The first sign that the ketogenic diet is of any benefit is a diminu-

tion in the number and severity of seizures. If the patient has been subject to both grand mal and petit mal, the attacks of grand mal usually stop or become less frequent before those of petit mal are markedly affected. Now and then, however, the results are dramatic and as soon as ketosis develops all seizures stop. In certain patients both types of attack disappear only to be replaced for the time being by headache of the migraine type, a symptom which finally disappears, however, if therapy is successful. This fact, together with the frequency with which migraine is associated with epilepsy, either in the patient or in some of his close relatives, suggests that the two conditions may depend in part upon some common cause (see page 266).

Another improvement which accompanies successful ketogenic therapy is a striking change in the personality of the patient which seems to indicate that the so-called "epileptic character" often regarded as causative by some psychologists is but a secondary manifestation of the general condition. Many children who have come to me for treatment have been considered a constant trial to all those in association with them because they were apprehensive, nervous, irritable, hard to manage, utterly unreasonable, and subject to occasional attacks of ungovernable temper. Other very young children have appeared markedly stupid and dull when first examined. After treatment has taken effect, the personality of all these patients has undergone a reversal and become quite similar to that of non-epileptic individuals. The patient has changed from an apprehensive, ner-

vous, and irritable person, who in a few instances could not tell the truth, to some one who is calm, placid, dependable, and truthful. Once or twice it has seemed as if a veil, which had hung before the mind, had been suddenly lifted to reveal the world to the child for the first time. One such patient, who apparently did not even know his own name, in two weeks' time not only learned his name, age, address, and the names of his family, but had made a beginning with his A, B, C's. He is now in school and progressing rapidly.

Comparable, but somewhat different changes take place in adults. In one middle-aged married woman, who had been under treatment for three years, the whole outlook on life has changed with a diminution in the frequency and severity of attacks. When dietary treatment began she was very depressed and could find no pleasure at all in life. She refused to see any of her friends or relations, and complained that she had an awful feeling of being some one else. As housework was the only occupation of which she was capable, she never left the house except to consult her family physician. Her present condition is in marked contrast to this. She is constantly surrounded by friends whom she sincerely enjoys, she takes an active part in church work, and is proud of what she has accomplished; she has no fear; and is no longer disturbed by the delusion of double personality. Her present attitude is consistently that of alert, active interest. What limitations exist are more than compensated for by the fact that life is now worth living. Constant dosage with luminal is

unnecessary, and she can dispense entirely with the drug except on the few occasions when she overdoes. Finally, the severity of her dietetic regimen is being gradually reduced without any increase in epileptic symptoms.

General physical improvement usually follows dietetic treatment of epilepsy. Patients who are obese lose weight, while those who are thin gain weight if the diet is suitably arranged. In both instances the health improves, and the patient feels better. It soon becomes evident also that the skin is clearer, the flesh firmer, the tone of the muscles more nearly normal, and the susceptibility to fatigue greatly diminished.

Factors Which Tend to Make Results Disappointing.—Mental degeneration at all times darkens the prognosis of epilepsy. Whether its effects result from lack of coöperation or from irreparable damage consequent to the epileptic condition is unknown, but certain it is that the epilepsy associated with mental deficiency does not respond to therapeutic measures as readily as does the uncomplicated type.

Coöperation in carrying out a course of treatment largely determines the beneficial effects of that treatment. Even the most rigid adherence to dietetic regulations may prove of little value without the full coöperation of the patient, whether he be child or adult. And even with this coöperation, assumption of the wrong attitude by a member of the family or an intimate friend may in large measure nullify the benefits derived from the diet and general hygienic

measures. The impatience, lack of judgment, and lack of tact of one parent can more than counterbalance all the efforts of the other parent. Because of this sensitiveness to environmental factors, treatment is usually particularly difficult when the parents are divorced, and special attention is required by patients who must continue to live in the midst of disturbed family situations. Another point to be remembered is that grandparents often do much harm unwittingly by giving too much sympathy or attention at the wrong time or in the wrong way.

Financial restrictions often seriously reduce the effectiveness of treatment, by making it impossible to take advantage of all therapeutic possibilities. With ingenuity and forethought, however, this handicap can be minimized and a means found of including the most important conditions in a practical regimen.

Age seems to play some part in the prognosis. As a rule, treatment is less successful in adults than in children, either because of some metabolic factors not yet understood, or because of the more complex life required of an adult. It may perhaps be that in children conversion of the metabolism from one type to another is easier than in adults because fewer bodily reserves have been built up to resist change, but no certain explanation for the difference has yet been found. One point which deserves emphasis, however, in considering this question is that a child usually comes for treatment while epilepsy is in a comparatively early stage, while an adult may come after the disorder has been established for many

years. And it is generally recognized that the longer a pathological habit has existed the more difficult it is to overcome.

Selection of Epileptic Patients for Treatment.—Fully effective therapy can be given only to patients who desire to submit to treatment, for only under these conditions can there be full coöperation between patient and physician. It is, nevertheless, necessary for most doctors to treat almost all patients who are sent to them for consultation, whether or not they are capable of responding to treatment. Experience has demonstrated that it is probably wasteful for the physician to spend a great deal of time and effort on patients with marked mental degeneration, and on those who are opposed to being treated, but in each instance all factors must be weighed before a decision is made as to the justification for undertaking a course of treatment which is necessarily long and arduous for all concerned. Certain cases of Jacksonian or symptomatic epilepsy have been known to respond to dietary therapy when the patient coöperated fully and all possible surgical measures had been employed to remove causative conditions.

CHAPTER XVIII

What to Teach an Epileptic Patient

Education is an important part of epileptic therapy, because full knowledge of the principles upon which the treatment is based makes it possible for the patient to coöperate more intelligently. In discussing the problems of diabetes, Joslin says that "Faithful treatment accomplishes wonderful results, but half-hearted treatment avails little." This is equally true of epilepsy and it should be strongly emphasized here that if the dietetic régime is not rigidly adhered to it might just as well not be undertaken.

Patients should realize that during ketogenic therapy more reliance is to be placed upon the diet than upon drugs, and that drugs are to be used only as adjuncts. Luminal may be employed at times to overcome certain temporary conditions, but it cannot produce in the body the chemical states which result from dietary therapy and are responsible for its effectiveness.

Every patient should have his own scales and know not only how to weigh out the different quantities of food included in the daily allowance, but how to compute this allowance for a diet of any given ratio. This means that he must understand the part

played by fat, carbohydrate, and protein in the ketogenic-antiketogenic balance, and how many calories each one of these food elements is to contribute toward the daily total.

He should also be familiar with the various methods of treating constipation. This necessitates knowing which laxatives are sugar-free and which cathartics can be used.

Thorough understanding of the principles of physical and mental hygiene is necessary as well, for physical and nervous strain can completely neutralize the good effects of the special diet. To avoid this pitfall the patient must be able to determine for himself the requisite amount of daily exercise, and to arrange a program which will fit in with his needs. He should learn that rest is desirable after the noon meal and that provision must be made for at least nine hours of sleep at a regular time each night. Comparable methods of obtaining adequate mental and nervous exercise and rest should be explained to him, and help should be given in outlining the desirable régime until he is sufficiently familiar with the principles involved satisfactorily to arrange his life for himself. It must not be forgotten, however, in giving supervision that the more independent a patient can be made the better off he will be no matter what his age.

CHAPTER XIX

Migraine

The association of migraine with epilepsy is sufficiently frequent to suggest that at least in certain types of the disorder there may be a common cause or background. It is not unusual for migraine to be found in the collateral branches of the family of an epileptic or in the parents and grandparents. Its periodic recurrence is typical. The fact that headaches, which simulate migraine, often precede or follow epileptic seizures is also noteworthy. If migraine and epilepsy have a common origin, treatment which successfully combats one condition should similarly affect the other. This has been found to occur in a few cases. Whether the best method of treatment finally proves to be dehydration or employment of the ketogenic diet, or both, only the future can tell.

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